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EMI Measurement and Mitigation Testing for the ARPA Hybrid Electric Vehicle Program

Anthony B. Bruno
Engineering and Technical Services Department

Oscar R. Zelaya
Submarine Electromagnetic Systems Department

Naval Undersea Warfare Center Division
Newport, Rhode Island

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Electromagnetic Interference; Electric Field Emissions; Magnetic Field Emissions; Electromagnetic Interference Abatement Techniques

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PREFACE

This document was prepared under Project No. S90805 to support the Electric Vehicle Dual-Use Initiative at the Naval Undersea Warfare Center (NUWC) Division, Newport, RI. The Program Manager for the Electric Vehicle Program is Russell L. Brown, (Code 40). This project is funded by the Advanced Research Projects Agency (John Gulley, Program Manager), with matching funds provided by the NUWC Dual-Use Technology Office (Code 10) and by the Office of Naval Research (ONR-362).

The technical reviewer for this report was Michael D. O'Bara (Code 3431).

Reviewed and Approved: 27 August 1996

Russell L Brown

R. L. Brown
Head, Engineering and Technical Services Department

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Electromagnetic interference (EMI) is an unintentional form of electromagnetic energy that can often affect the performance of both the system creating the interference and external systems. EMI typically manifests itself as a loss of performance in systems that are exposed to the interference, e.g., communication range is reduced, computers malfunction, or monitoring systems fail. Various electric vehicles (EVs) were measured to evaluate their potential EMI emissions when used in today's hostile commercial electromagnetic environment. Measurements were made in accordance with specification SAE J551 and MIL-STD-461C where applicable. Vehicle emissions were measured using standard open-field techniques and, for reference, several vehicles were measured in a screen room using a dynamometer. Correlation in the measurements taken from the electric vehicles in both testing scenarios was observed. Measured field levels in most cases were below the specified limit line. In cases where field levels exceeded specification limits, measured electric and magnetic field levels were compared to Navy exposure field limits. Measured field levels were found to be much lower than the levels established by the Navy exposure field limits.

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EXECUTIVE SUMMARY

Electric vehicles (EVs) have military as well as civilian applications. For example, using an electric motor drive system in battle space affords a higher degree of stealth than does an internal combustion engine. Thus, identifying electromagnetic interference (EMI) issues that compromise stealth is essential. This study measured electromagnetic emissions from military and civilian vehicles to create a database that can help identify those EMI issues.

EMI is an unintentional form of electromagnetic energy that often affects the performance of the system creating the interference and other external systems. EMI typically manifests itself as a loss of performance in systems that are exposed to the interference, e.g., communication range is reduced, computers malfunction, or monitoring systems fail. Various EVs were measured to evaluate their potential EMI emissions when used in today's hostile commercial electromagnetic (EM) environment. Measurements were made in accordance with specification SAE J551 and MIL-STD-461C where applicable. Vehicle emissions were measured using standard open-field techniques and, for reference, several vehicles were measured in a screen room using a dynamometer. Each vehicle was placed, in turn, in the test area with power applied to all components and systems that could be energized while the vehicle was in idle mode. The vehicle was then jacked up and run at 25 mph to simulate driving conditions.

Measurements were made with various calibrated antennas designed to detect electric and magnetic field emissions in various frequency ranges. Electric fields were measured from 9 kHz to 1 Ghz; magnetic fields were measured from 30 Hz to 50 kHz. For each test, the vehicle was placed in a clear area of a 15-m radius. The various antennas were placed 1 m and 10 m from the vehicle for electric field measurements and 7 cm and 1 m for magnetic field measurements. Measurements were also performed on a selected group of vehicles in an anechoic shielded enclosure at the Dayton T. Brown Inc. facility (Bohemia, NY), where the screen room is equipped with a dynamometer that can load the vehicle to simulate driving conditions and can provide useful measurements from 10 kHz to 10 GHz. Measurements from the screen room were compared with the open-field measurements to determine if there were any significant differences.

Measurements were performed on the following electric vehicles: (1) Connecticut Municipal Electric Energy Cooperative (CMEEC) GMC Sonoma pickup truck - College conversion dc drive, measured at Fishers Island, NY; (2) Kaman Electromagnetics Corporation, Hudson, MA, Hybrid Electric 40-ft heavy-duty transit bus, measured at Hudson, MA; (3) Warner Robins Air Force Base, Macon, GA, Dodge Dakota pickup truck - ac controller, measured at Macon, GA; and (4) Solectria Corporation: (a) Solectria Force - Geo Metro conversion ac controller, measured at Fishers Island, NY and at the Dayton T. Brown facility, Bohemia, NY; (b) Geo Metro preconversion internal combustion engine (ICE), measured at the Dayton T. Brown facility;and (c) selected controllers, measured at the Naval Undersea Warfare Center (NUWC) Detachment, New London, CT.

The following chart shows the types of measurements, magnetic and electric (designated "M" and "E"), performed on the test vehicles. Representative data spectra for each measured vehicle are in the text and appendix. Each data plot contains data collected from the test and the corresponding SAE J551 electric field limit line and the MIL-STD 461C magnetic field limit line. The MIL-STD 461C limit line is the standard limit used by the military and is incorporated into the software to generate the data plots from EMI sources taken at 7 cm with a loop antenna. The MIL-STD is used because the SAE does not have a low-frequency magnetic field specification limit. Based on the military specification, one may infer that any magnetic field emissions coming from an electric vehicle will be considered if they degrade the performance of other vehicles or systems located within 7 cm. A 7-cm distance, however, will not usually be met except between internal components. Furthermore, the 7-cm distance can be used to troubleshoot the electric vehicles and locate the highest radiating magnetic sources. Therefore, taking measurements at 1 m from the electric vehicles or relaxing the specification limit by 10-20 dB will be a more realistic approach for evaluating the EMI radiated from the electric vehicles.

Vehicle	Converter Type	Open-Field	Screen Room
Sonoma	CMEEC	M, E	M, E
40-ft Bus	Kaman	M, E	--
Dakota	Westinghouse	M, E	--
Force	Solectria	M, E	M, E
Geo Metro	ICE	--	M, E
Controllers	Solectria	--	M, E

Electric field emissions were measured at 1 m and 10 m from each of the vehicles tested. No electric field emissions were observed above the SAE limit line that could not be identified as corresponding to background emissions. This result was not unanticipated because EVs are essentially current sources that have associated magnetic fields. ICEs, on the other hand, are electric field radiators because of their transient behavior (attributed to spark plugs).

Collected data show that the open-field measurement technique is valid and gives measurements equivalent to similar measurements made in special screen-room facilities. The cost of open-field measurements is typically an order of magnitude lower than their screen room equivalents. The only constraint that open-field measurements impose is that the background noise be at least 20 dB below the expected measurement levels. This condition can be met by choosing areas that are electrically quiet, i.e., areas that are away from manmade sources of electrical noise.

The major sources of radiation from the electric vehicles considered were motor controllers, dc to dc converters, power steering motors, brake vacuum pumps, distribution boxes, cable harnesses, and drive motors. These devices should be considered for electromagnetic compatibility (EMC) abatement techniques such as filtering, gasketing, shielding, and rerouting of components or cables to meet the requirements and to avoid the potential risk of affecting the performance of other vehicles or systems. Solectria controllers measurements show that simple and inexpensive EMC techniques can reduce magnetic field levels by 10 dB.

Measured field levels in most cases were below the specified limit line. When field levels exceeded the specified limits, measured electric and magnetic field levels were compared with Navy exposure field limits and found to be much lower than the levels established by those limits.

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EMI MEASUREMENT AND MITIGATION TESTING FOR THE ARPA HYBRID ELECTRIC VEHICLE PROGRAM

INTRODUCTION

Electromagnetic interference (EMI) is an unintentional form of electromagnetic energy that can affect the performance of both the system creating the interference and external systems. EMI typically manifests itself as a loss of performance in systems that are exposed to the interference, e.g., communication range is reduced, computers malfunction, or monitoring systems fail. An extreme example of EMI is the case of electric vehicles (EVs) causing the inadvertent activation of bomb-release mechanisms on aircraft.

Identification of EMI issues that affect military EVs in battle space is critically important. This study measured electromagnetic field emissions from both military and civilian vehicles in an effort to build an EV emission database that can be used to identify EMI issues that affect EV performance.

This document presents the information on the EVs that were tested to evaluate the potential emissions of EVs when used in today's hostile commercial EM environment. The risks associated with particular emissions were assessed, including the possibility of the EV creating undesirable EMI emissions that can affect other systems. In addition, electromagnetic compatibility (EMC) abatement techniques are recommended when appropriate. When the responsible party implemented the recommended corrective measures, a retest of the particular vehicle or component was performed to ensure desired performance.

EXPERIMENTAL PROCEDURE

Electric and magnetic field emissions from EVs were measured in accordance with Society of Automotive Engineers specification SAE-J551 [1]. This specification is for open-field measurements with the vehicle under test jacked up so that the drive mechanism can be engaged. Open field means that the measurements are performed in an electromagnetically quiet area. The background environment consisting of additional manmade noise sources is at or near the natural background level. The Naval Undersea Warfare Center (NUWC) Division Newport's electromagnetic (EM) testing facility at Fishers Island, NY, is an EM quiet area and has been used to perform several of the EV tests. Other areas away from commercial noise sources are also acceptable. With the background level established, the EVs were tested. Each vehicle was placed, in turn, in the test area with power applied to all components and systems that could be energized while the vehicle was in idle mode. These components would vary from vehicle to vehicle but usually consisted of power steering motors, brake pumps, motor controllers, and dc to dc converters. In the idle position, the main drive motor controllers were powered—but not active—and the drive motors were not powered. Each vehicle was then jacked up and run at a constant speed (25 mph) to simulate driving conditions.

Measurements were made with various calibrated antennas designed to detect electric and magnetic field emissions in various frequency ranges. Electric fields were measured from 9 kHz to 1 GHz and magnetic fields were measured from 30 Hz to 50 kHz in accordance with MIL-STD- 461C [2]. The vehicle was placed in a clear area of a 15-m radius. The various antennas were placed at 1 m and 10 m from the vehicle for electric field measurements and at 7 cm and 1 m for magnetic field measurements. Zelaya [3] describes the open-field measurement test procedure in detail, including calibration, antenna factors, antenna patterns, and polarization.

Measurements were also performed on a selected group of vehicles in an anechoic shielded enclosure at the Dayton T. Brown Inc. facility located in Bohemia, NY [4]. These same vehicles had been tested under open-field conditions earlier. The anechoic chamber, which is 32 ft wide by 30 ft long and 12 ft high, is designed to provide useful measurements from 10 kHz to 10 GHz. The screen room is equipped with a dynamometer that can load the vehicle to simulate driving conditions. Measurements from the screen room were compared with the open-field measurements to determine if there were any significant differences.

An F. W. Bell gauss/tesla meter was used to look at the strength of the magnetic fields around the "hot spots" (areas where electromagnetic emissions are usually high) measured with the loop antenna. The Bell meter displayed the relative strength of the magnetic fields around the components and was used to pinpoint the location of the magnetic field source. In some instances, the vehicles were driven to see if any significant differences were discernible in the data. In addition, an F. W. Bell extremely low frequency (ELF) meter was used inside the vehicles while they were driven to determine if any significant radiation at power line frequencies was present.

CALCULATION OF MAGNETIC FIELD LEVELS

To find the magnetic field level of the out-of-specification limit emissions in milligauss (mgauss) given by the spectrum analyzer reading in dB pico-tesla (dBpT), the following conversion factor was used: 1 gauss = 10^8 pT or 0 dBG = 160 dBpT or -160 dBG = 0 dBpT. For illustration, consider how the magnetic field level at 240 Hz for the Kaman Bus in figure 10 was calculated. First, one locates the 240 Hz out of specification B-field emission, which is approximately 113 dBpT; then, using the conversion factor -160 dBG = 0 dBpT, one finds that the magnetic field emission level of 113 dBpT corresponds to the value of -47 dBG; finally, taking the anti log function to the value, one obtains the expected value: B-field level = antilog(-47/20) = 0.00447 Gauss = 4.47 mGauss.

MEASUREMENTS

Measurements were performed on various electric vehicles. These vehicles were available to NUWC Division Newport on loan from the manufacturer or were available as a group for vehicle demonstrations. The following numbered items identify the equipment measured (vehicles measured at Smuggler's Notch are reported in reference 5.

1. Smuggler's Notch, VT:
   a. Solectria E-10 (three different vehicles)
   b. EVs of America S-10
   c. U.S. Electricar E-10
   d. Horlacher.

2. Connecticut Municipal Electric Energy Cooperative (CMEEC): GMC Sonoma pickup truck - College conversion dc drive, measured at Fishers Island, NY.

3. Kaman Electromagnetics Corporation, Hudson, MA: Hybrid Electric 40-ft heavy-duty transit bus, measured at Hudson, MA.

4. Warner Robins Air Force Base, Macon, GA: Dodge Dakota pickup truck ac controller, measured at Macon, GA.

5. Solectria Corporation:
   a. Solectria Force - Geo Metro conversion ac controller, measured at Fishers Island, NY, and the Dayton T. Brown facility , Bohemia, NY.

   b. Geo Metro - preconversion internal combustion engine (ICE), measured at the Dayton T. Brown facility.

   c. Selected controllers, measured at NUWC, New London, CT.

Table 1 summarizes the types of measurements performed. Figure 1 illustrates a typical open-field test setup, and figure 2 shows a representative arrangement of the test equipment.

Table 1. Measurement Summary

Vehicle	Converter Type	Open Field	Screen Room
Sonoma	CMEEC	M, E	M, E
40-ft Bus	Kaman	M, E	--
Dakota	Westinghouse	M, E	--
Force	Solectria	M, E	M, E
Geo Metro	ICE	--	M, E
Controllers	Solectria	--	M, E

M = Magnetic; E = Electric

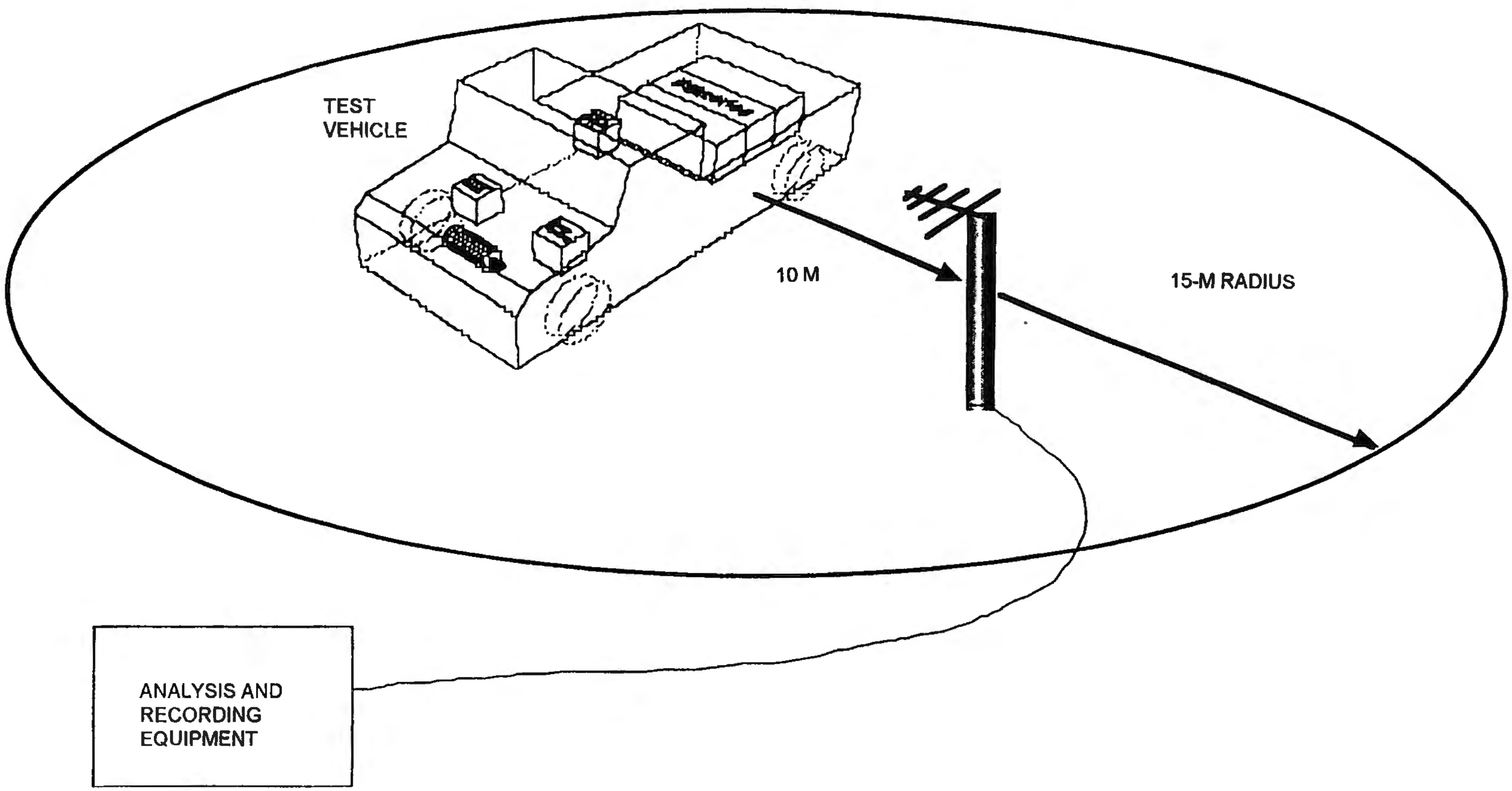


Figure 1. Typical Open-Field Test Setup

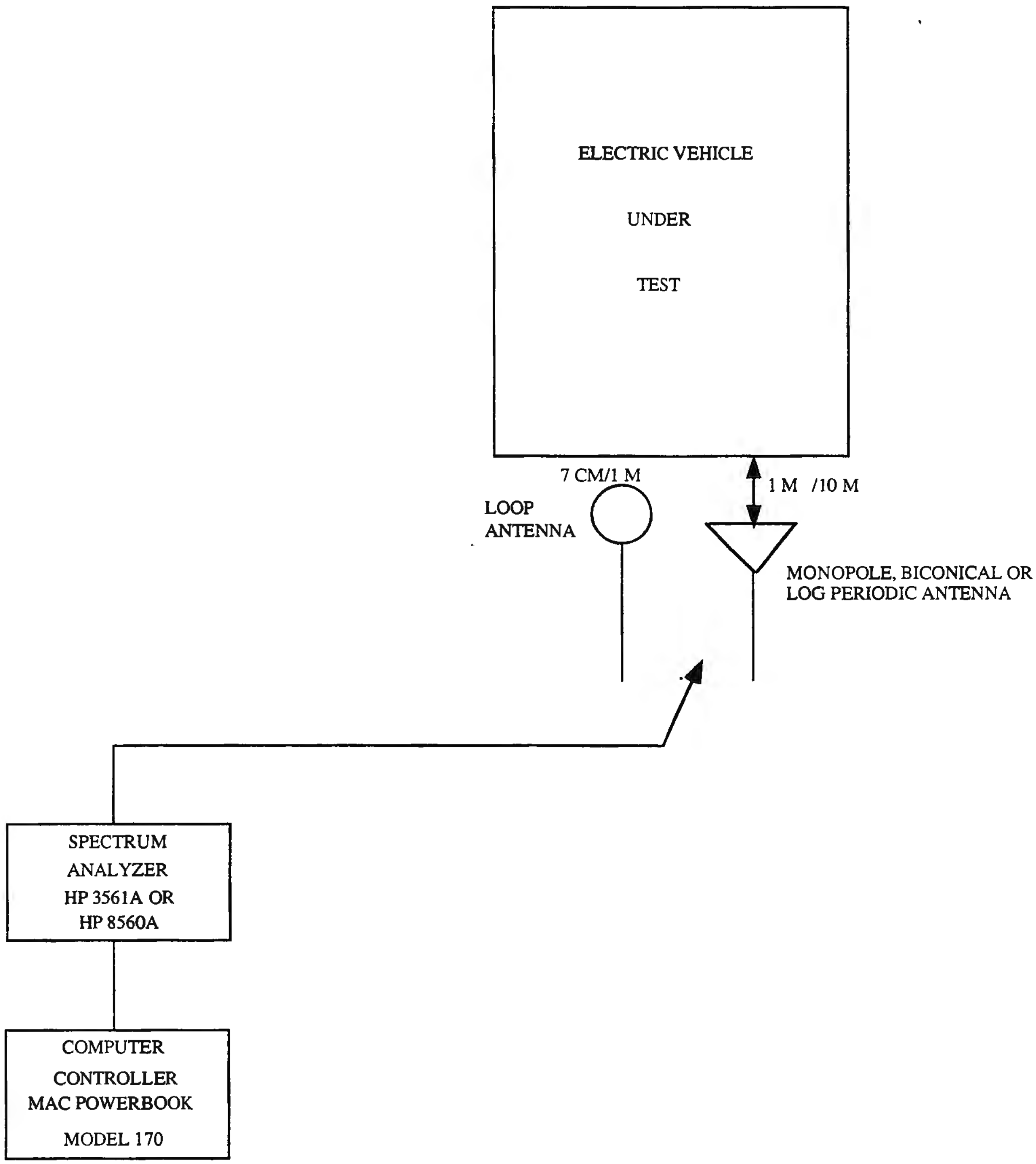


Figure 2. Electric/Magnetic Field Open-Field Test Setup

Various electromagnetic receiving antennas were placed on a nonmetallic tripod, and emissions were measured over the antennas' frequency ranges. The raw data were reduced with a spectrum analyzer, and results were plotted and stored on a computer disk for later retrieval. Table 2 lists the various antennas, frequency ranges, and analysis bandwidths. Each antenna was located at a specific range from the vehicle, i.e., 7 cm and 1 m for magnetic measurements and 1 m and 10 m for electric measurements. Each of the four sides of a vehicle could be observed with the complete suite of antennas, ranges, and polarization. Spot checks were performed first to determine if one of the vehicle sides contained electromagnetic hot spots. Given the component layout of a particular vehicle, areas for concentration are typically associated with high-current devices, i.e., motor controllers and the electric motors. Therefore, most measurements were confined to the vehicle front and driver's side. Additional measurements were made inside the vehicle at the driver's location.

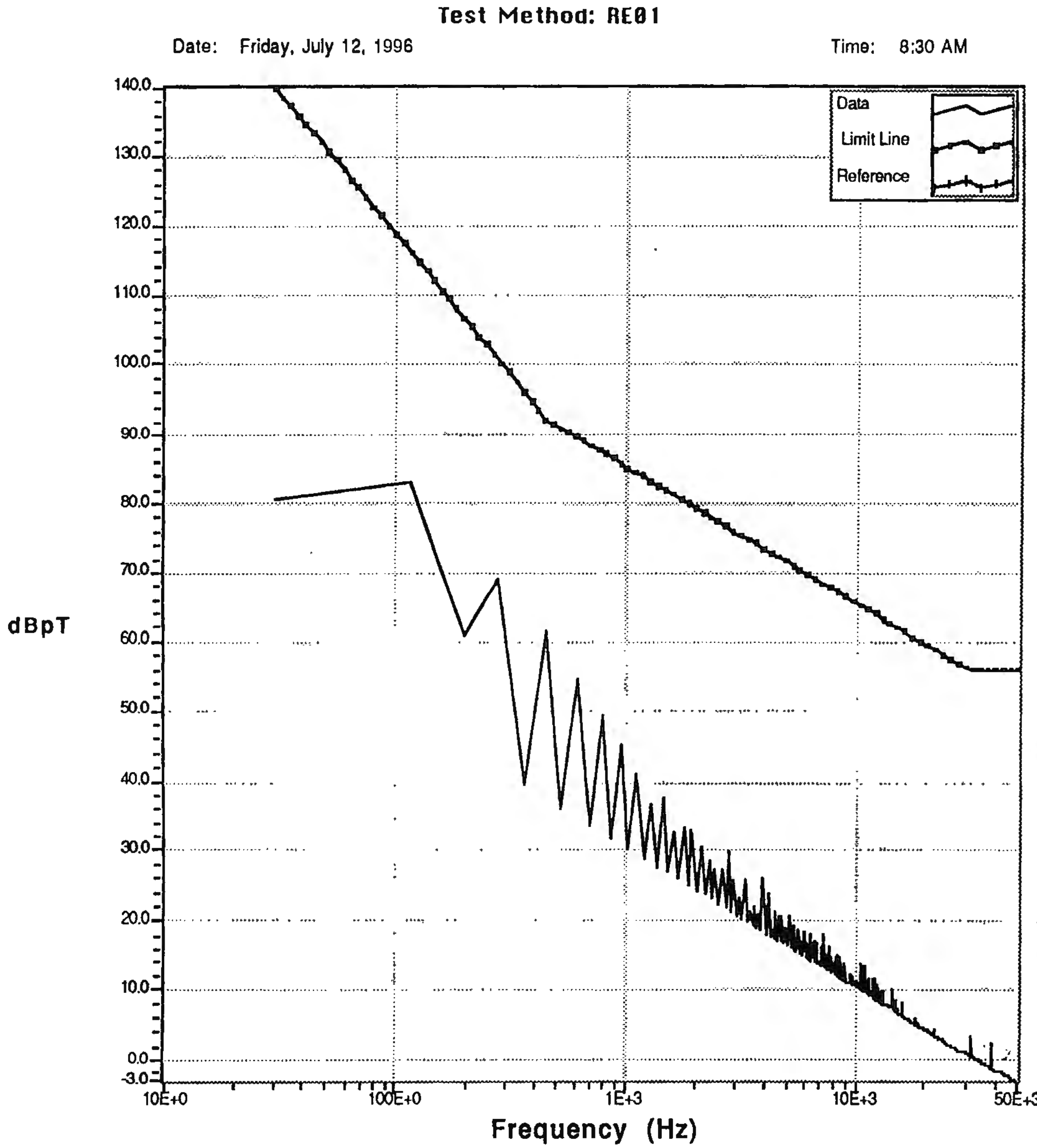
Table 2. Open-Field Antenna Characteristics

Antenna	Frequency Range	Polarization	Analysis Bandwidth
EMCO 5.5-in. Loop	30 Hz - 100 kHz	2 H, 1V	10 , 30 Hz
Monopole Antenna	1 kHz - 60 MHz	V	1 kHz
Biconical Antenna	20 MHz-300 MHz	V, H	10 kHz, 1MHz
Log Periodic Antenna	300 MHz - 1 GHz	V,H	10 kHz, 1MHz

V = Vertical; H = Horizontal

To interpret the emissions data properly, a set of background measurements were also made prior to the introduction of the vehicle under test. Figure 3 shows typical magnetic field background measurements performed at the Fishers Island facility just prior to the Sonoma GMC pickup truck tests. The figure shows that the background noise between 1 kHz and 50 kHz is approximately 45 dB below the MIL-STD limit line. Figure 4 shows the corresponding electric field background measurement. The background noise measurements show that the natural electromagnetic background spectrum is at least two orders of magnitude below the limit line imposed by either J551 or MIL-STD-461C. This fact ensures that electromagnetic observations on the test vehicle are not contaminated by background noise. Background measurements are made at all the open-field measurement locations. In all cases the background noise was similar to that shown in figures 3 and 4.

In the following paragraphs, the measurements made on each of the listed vehicles or components are summarized. The selected magnetic and electric field spectra shown represent the highest levels observed for a particular vehicle. The complete set of worst-case magnetic field and electric field measurements for each vehicle are shown in the appendix. In this case, a set of measurements is defined as a complete spectrum of magnetic and electric field data at a particular range and for the vehicle side that gave the worst-case data. Note that magnetic field worst case and electric field worst case are not necessarily on the same vehicle side. These differences are noted in the annotations on the individual plots. Where appropriate, open-field data are compared with comparable data from the Dayton T. Brown screen room measurements.



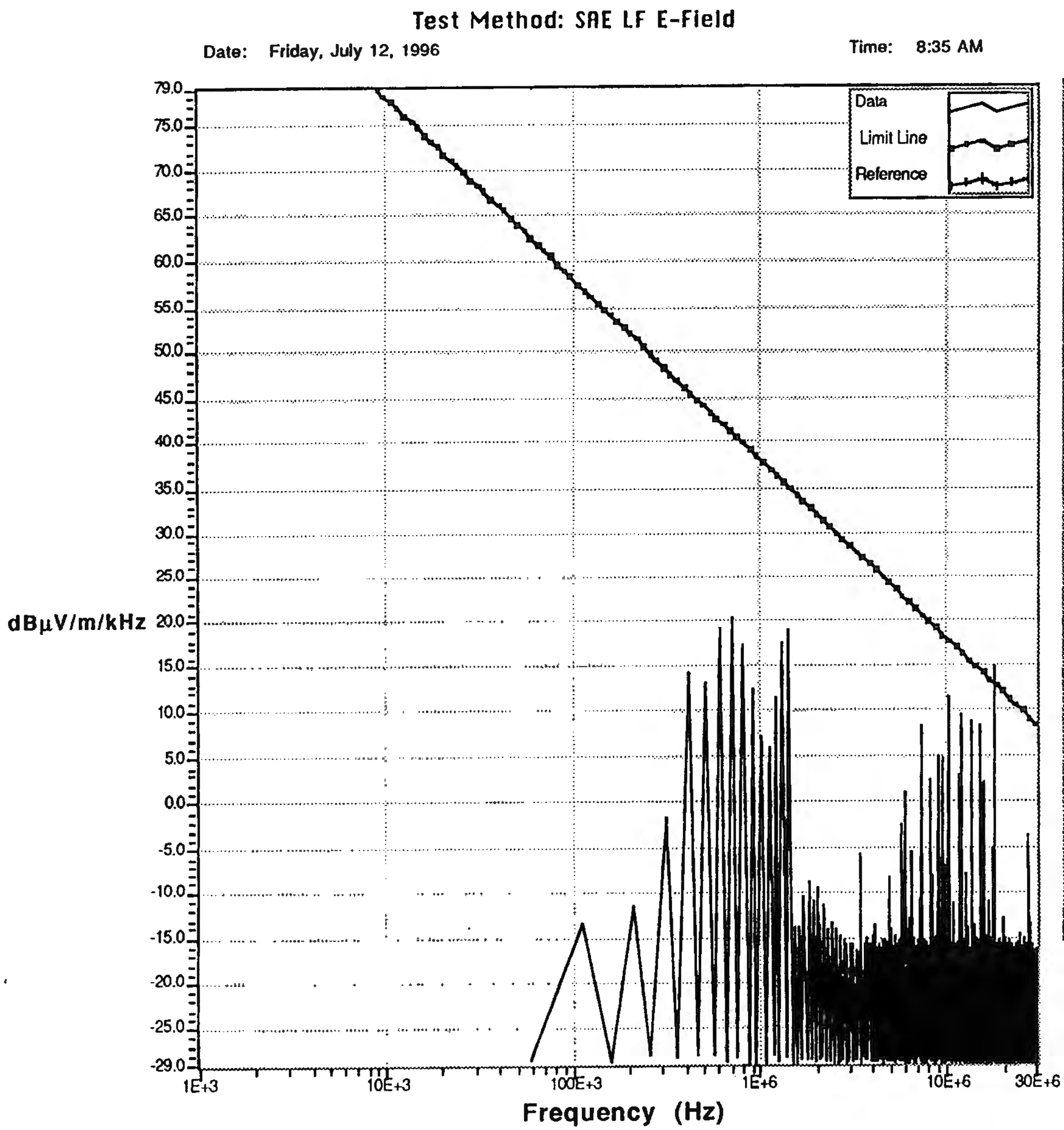
Test Info Table

8/3/95	11:12 AM
Car	CMEEC Truck
Test site	Fishers Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	EMCO 5 1/2" Loop SN 2163
Amplifier:	HP8447F (26db)
BandWidth:	1 0

Remarks

Magnetic Field Measurements taken at Ambient Condition

Figure 3. CMEEC Vehicle in Open Field, B Field Measurement Taken at Ambient Condition



Test Info Table

8/3/95	9:58 AM
Car	CMEEC Truck
Test site	Fishers Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	No Current Probe
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurements taken at Ambient Condition

Figure 4. CMEEC Vehicle in Open Field, E Field (0.014-30 MHz) Taken at Ambient Condition

Table 3 summarizes the antennas used at the Dayton T. Brown screen room facility. Magnetic field measurements were performed at 7 cm in accordance with MIL-STD-461C, and electric field measurements were performed at 1 m in accordance with SAE-J551.

Table 3. Screen Room Antenna Characteristics

Antenna	Frequency Range	Polarization	Analysis Bandwidth
Loop	30 Hz - 50 kHz	H, V	10 Hz
41 in Rod	9 kHz - 30 MHz	V	1 KHz
Biconical	30 MHz - 200 MHz	V, H	10 kHz
Double Ridge Guide	200 MHz - 1 GHz	V,H	1 MHz

V = Vertical; H = Horizontal

Magnetic field data are presented in dB re 1 pico-tesla (pT). These units are specified in MIL-STD-461C and thus are also used here. A pT is 10^{-12} tesla, 1 gauss = 10^8 pT, and 1 mG = 10^5 pT (100 dB re 1 pT). Electric field measurements are presented in dB re 1 µV/m per Mhz bandwidth. This unit is specified in both MIL-STD-461 and SAE-J551.

CMEEC GMC SONOMA PICKUP TRUCK

Although not considered a state-of-the-art design, the Sonoma was at NUWC Division Newport's disposal for testing purposes, thus making it the ideal vehicle for an extensive research, development, test, and evaluation (RDT&E) effort. The Sonoma was measured in both the open field and the Dayton T. Brown screen room. The vehicle is powered by a 28 hp, 9 in.-diameter 120-Vdc electric motor with a Curtis motor controller and is a solar car conversion using the factory drive train and five-speed manual transmission. The power source was Excide GC5 batteries. The Sonoma was the quietest vehicle tested with respect to electromagnetic emissions. Figures 5 and 6 show the Sonoma at the open-field site. The vehicle was jacked up and running (no load) at 35 mph. The figures show a loop antenna at 1 m and a whip antenna at 10 m from the Sonoma, respectively. Figure 7 shows the Sonoma in the Dayton T. Brown screen room. The rear wheels are on the dynamometer, and the vehicle is running at 25 mph under a no-load condition.

Figures 8 and 9 show the magnetic field measurements taken at the open-field site and in the shielded room, respectively, for the GMC Sonoma. Correlation between the two signatures can be observed from the emission levels to the specification level. Similarly, figures 10 and 11 show the electric field data for the open field and the shielded room measurements and, again, correlation is observed in their emission levels. No magnetic field emissions above the specification limit are observed for the Sonoma GMC pickup truck. However, figure 12 for the open-field data shows two electric field emissions above the specification limit at 12 and 20 MHz when compared with the background data in figure 4.

Figure 5. CMEEC Car in Open Field, B Field Measurement

Figure 6. CMEEC Car in Open Field, E Field Measurement

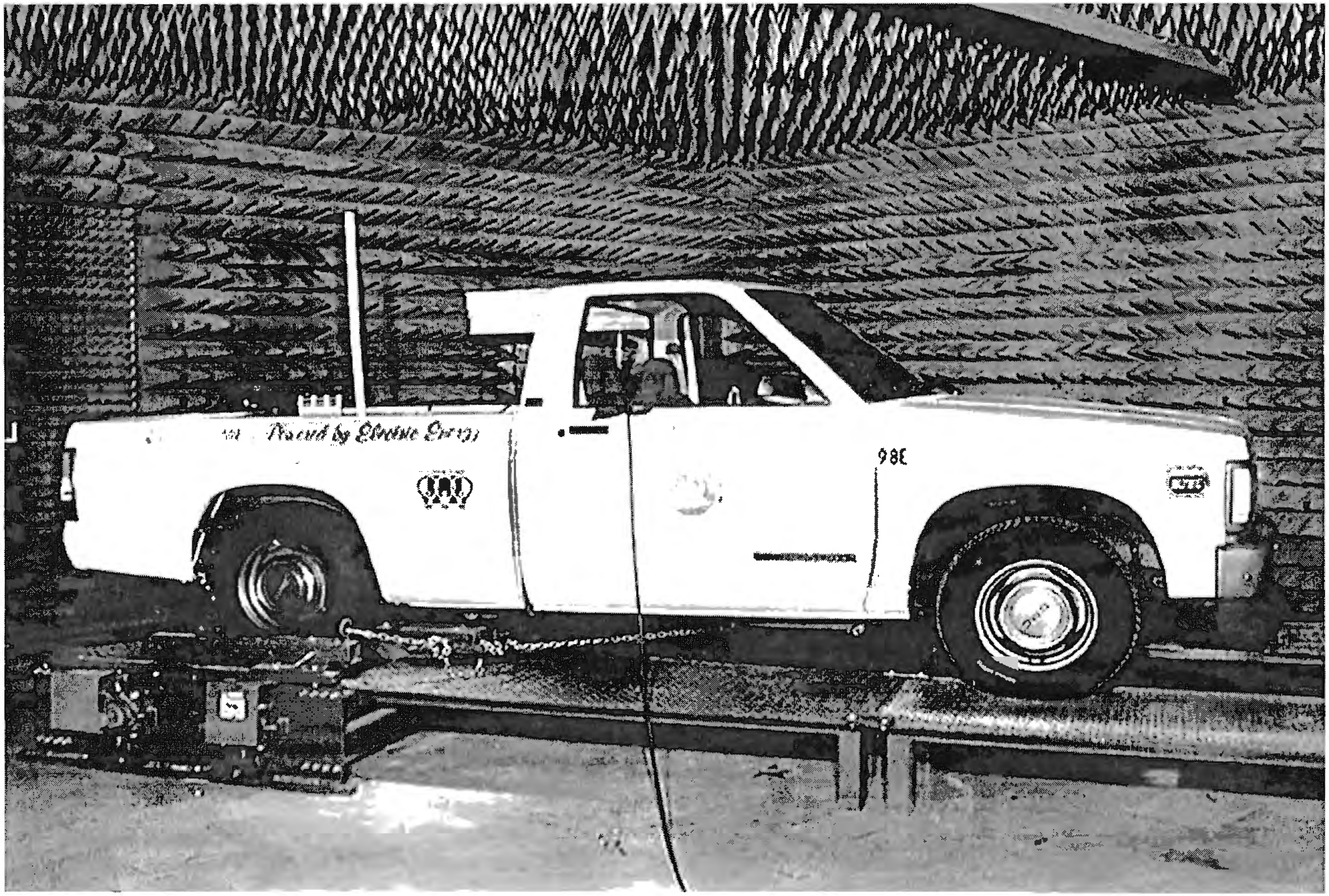
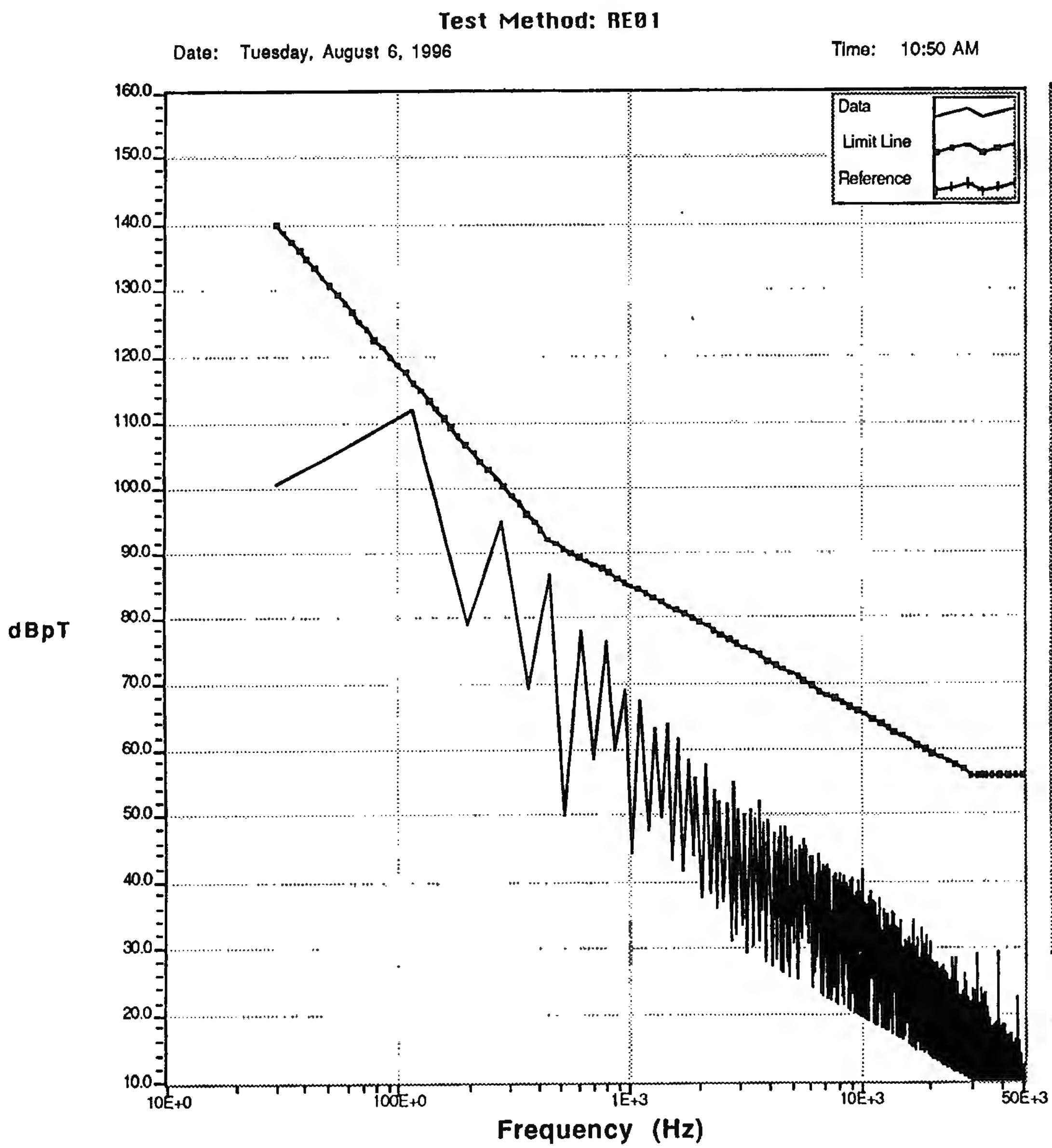


Figure 7. CMEEC Vehicle in Anechoic Chamber Test



Test Info Table

8/3/95	3:55 PM
Car	CMEEC Truck
Test site	Fishers Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	EMCO 5 1/2" Loop SN 2163
Amplifier:	None
BandWidth:	1 0

Remarks

Magnetic Field Measurements with Loop antenna located at 1 meter facing the driver side of the car and 1 meter up from the ground. Car is jacked up and running at 35 mph.

Figure 8. CMEEC Vehicle in Open Field, B Field Measurements Taken 1 m from the Driver's Side

Dayton T. Brown Inc.

MIL-STD-461C RE01 CLASS A3

Date :	09/18/95	Time :	15: 25: 40.71	EMC-11 SETTINGS		SPECS
Technician :	V.MIrkov V.M.	Job Number	: 409175-00-000	Detector	Peak	1) MIL-STD-461C RE01
Customer:	McLaughlin Research	Test Number	: 9175003	Bandwidth	Per Table	2)
Test Item :	CMEEC	Sensor Loc.	: Driver Side	Impedence	50 Ohm	3)
Mode of Op. :	Drive	Sensor Pol.	:	RF Atten.	60 dB	4)
Serial No. :	291-GRO	Ext. Atten.	: 0 dB	High Pass	16 Hz	DATA FILE : 9175003.D11
				Low Pass	50 kHz	
				Output	IF	

R. [signature]

Comment : Speed at 25MPH & 25 Amps

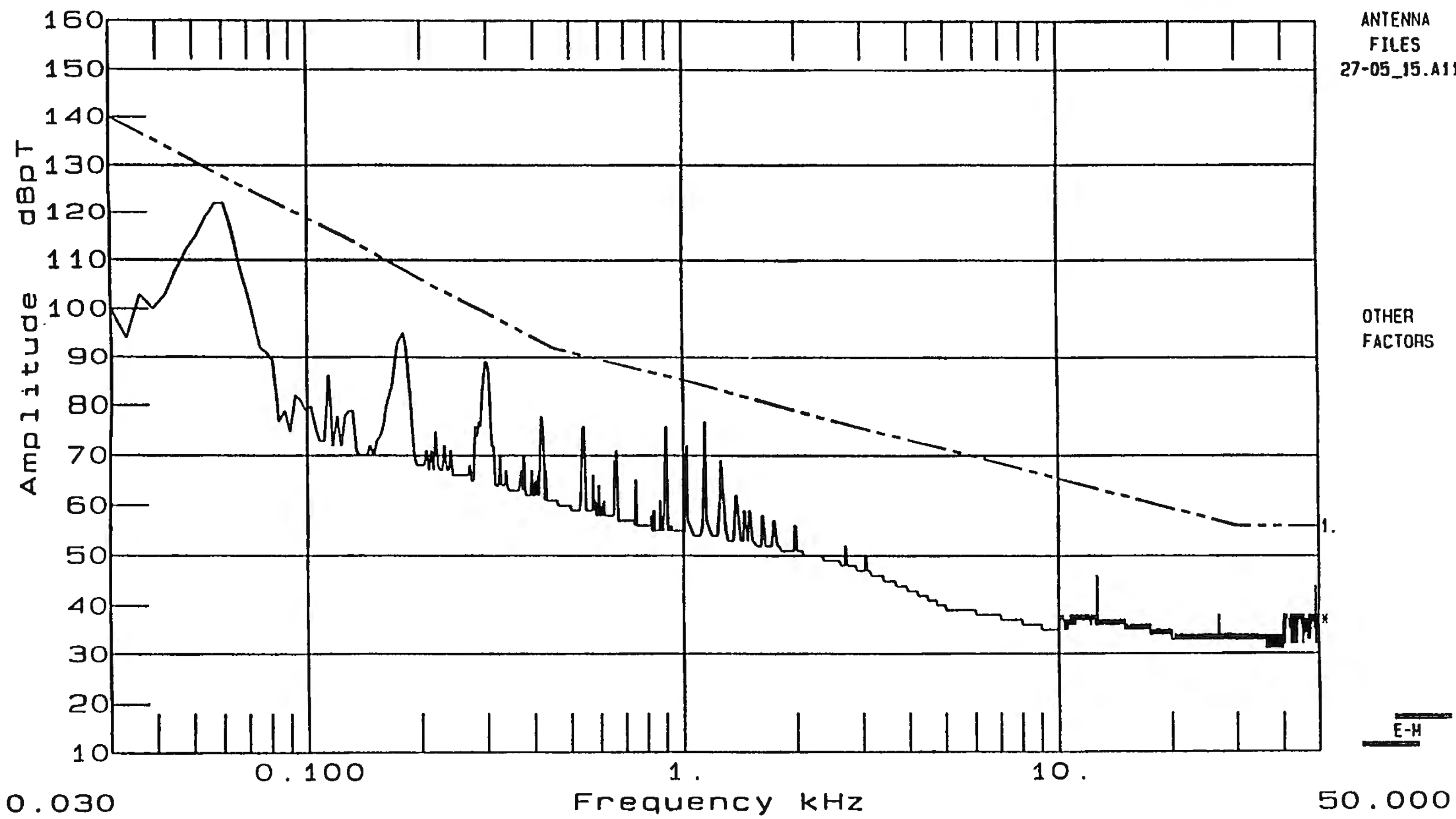
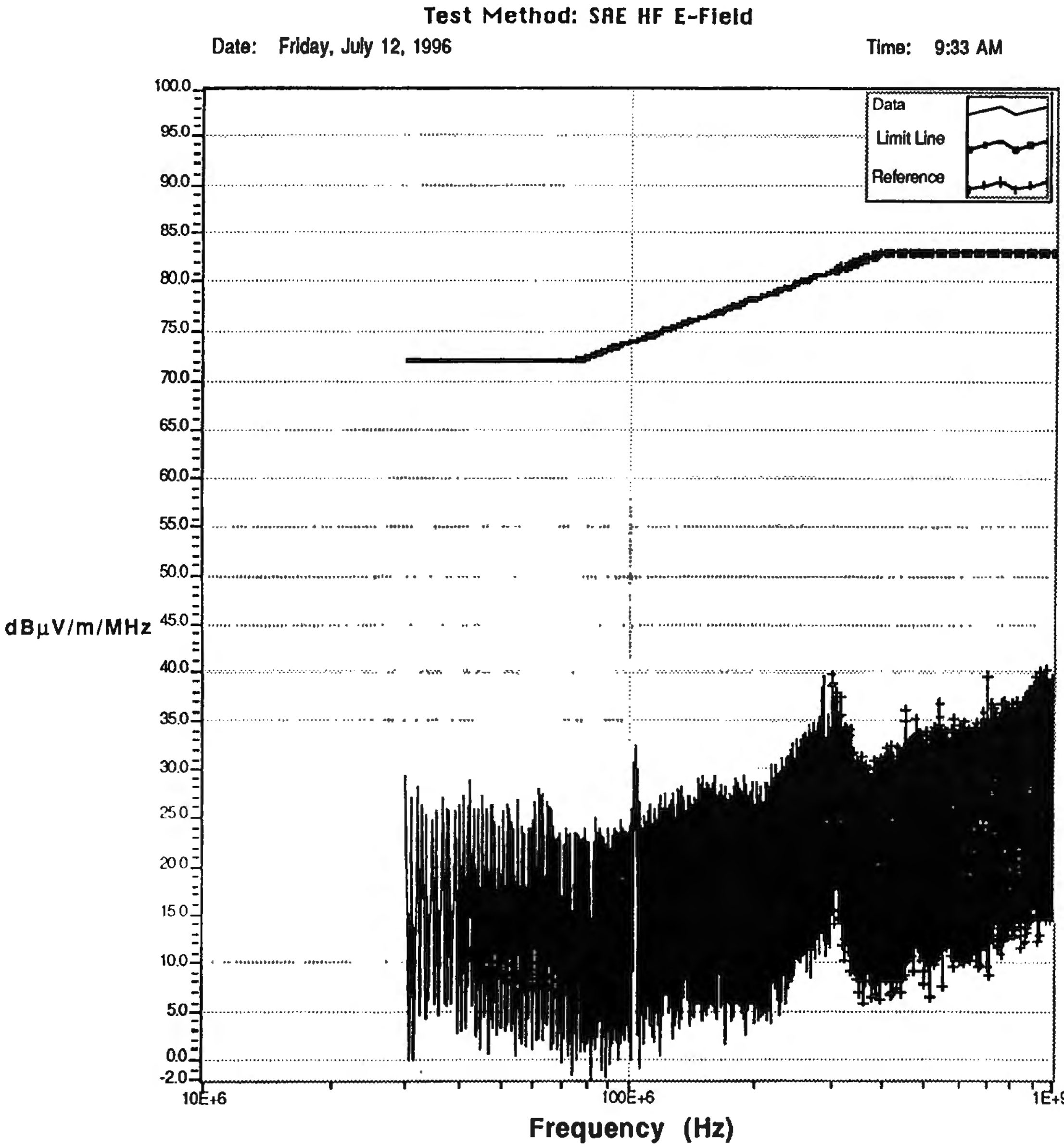


Figure 9. CMEEC Vehicle in Anechoic Room, B Field Measurements Taken at the Driver's Side



Test Info Table

8/3/95	2:06 PM
Car	CMEEC Truck
Test site	Fishers Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	1000000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	1000000

Remarks

Electric Field Measurements taken at 35 mph in 5th gear condition with car jacked up and antenna located at 1 m from the Front side section of the car

Figure 10. CMEEC Vehicle in Open Field, E Field (30-1000 MHz) Taken 1 m from the Front Side

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/18/95	Time :	17:08:07.81	EMC-30 SETTINGS		SPECS	
Technician :	C. Treadwell	Test Equip. :	409175-00-000	Detector	Peak	1) J551 @ 1 Meter	
Test Method :		Test Number :	9175006	Bandwidth	Per Band	2)	
Equipment :	CMEEC	Sensor Loc. :	1 METER IN FRONT	Dwell	20 msec.	R. Nardiello	
Mode of Op. :	Drive	Sensor Pol. :	HORIZONTAL	RF Atten.	0 dB		
Serial No. :	291-GRO	Ext. Atten. :	0 dB	IF Atten.	0 dB		

Comment : TEST ITEM NOT UNDER LOAD. 2.5 MPH, 25A

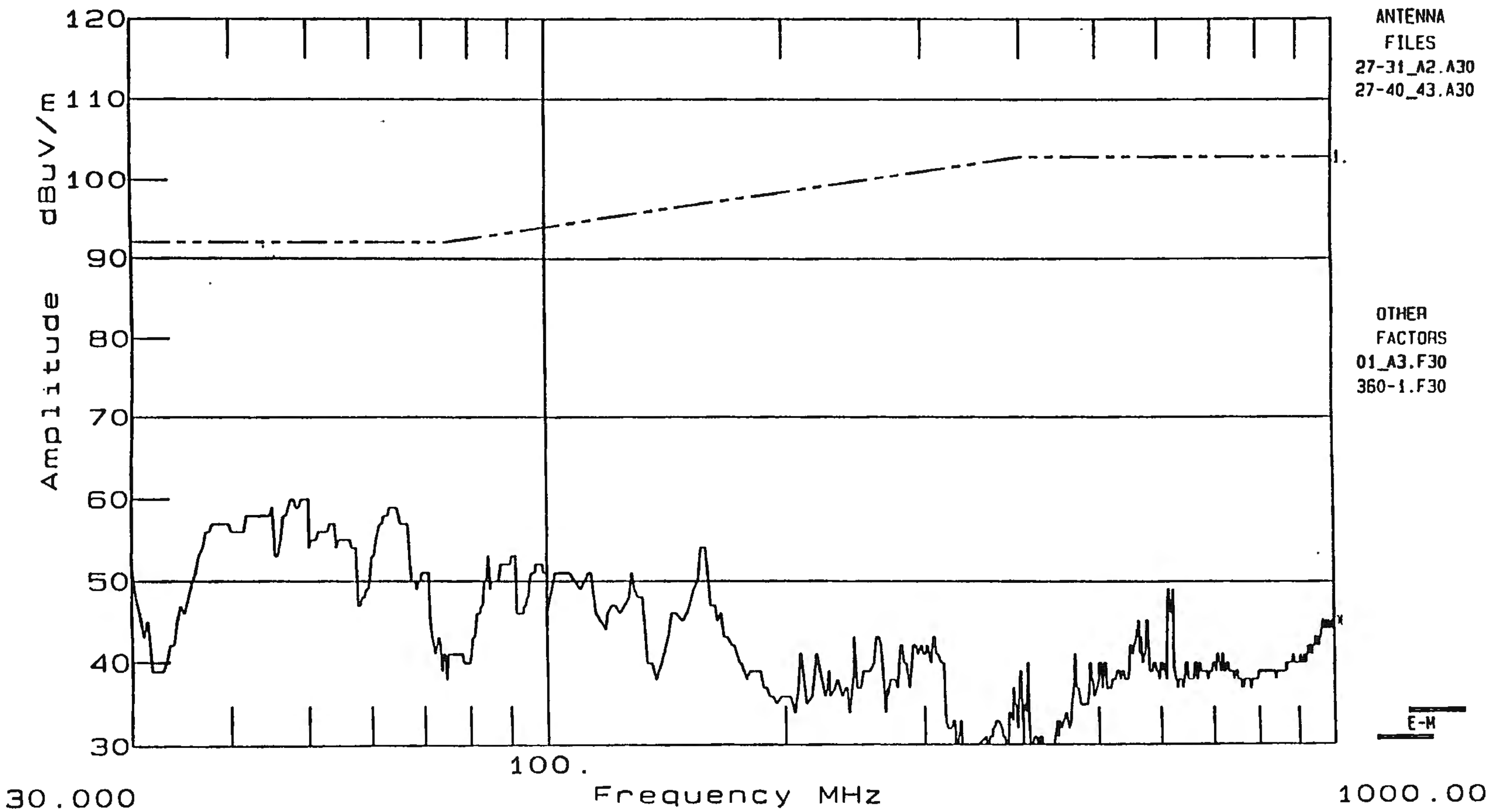
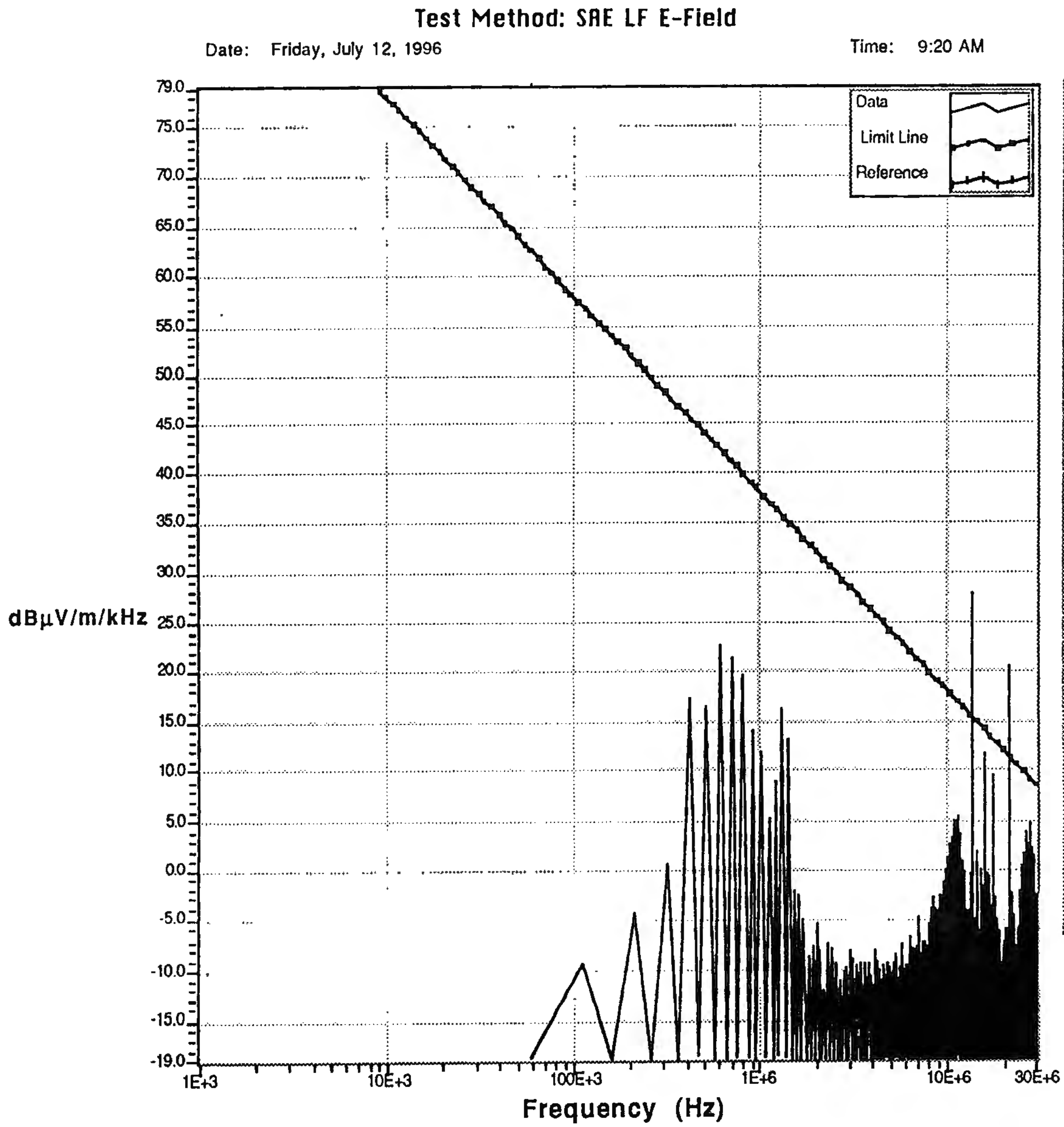


Figure 11. CMEEC Vehicle in Anechoic Room, E Field Measurements Taken 1 m from the Front Side



Test Info Table

8/3/95	2:03 PM
Car	CMEEC Truck
Test site	Fishers Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	BB Active MP SAS-200/550
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurements taken at 35 mph in 5th gear condition with car jacked up and antenna located at 1 m from the Front side section of the car

Figure 12. CMEEC Vehicle in Open Field, E Field (0.009-30 MHz) Taken 1 m from the Front Side

HYBRID ELECTRIC 40-FT HEAVY-DUTY TRANSIT BUS

The hybrid electric 40-ft heavy duty transit bus is a joint venture between Kaman Electromagnetics Corporation and NovaBus of America. The Kaman bus utilizes a unique, parallel, hybrid electric drive system, consisting of a 190-kW, brushless, dc permanent magnet traction motor; a propane-fueled rotary engine generator set; nickel cadmium batteries; and control and power-conditioning electronics. A 120-kW generator set supplies auxiliary power, propulsion power, and battery recharging over specific operating conditions. Figures 13 and 14 show the bus and the loop antenna set up inside the bus, respectively. Figure 15 shows a block diagram of the various electrical components of the bus with respect to the magnetic field measurement locations.

Figure 16 shows the magnetic field data for the Kaman bus, taken inside, 7 cm from the floor near a typical passenger seat. The measurement location is shown on the bus electrical layout in figure 15. The bus was jacked up and running at 14 mph. Several magnetic field emissions are above the specified limit of 240 Hz to 45 kHz. At 240 Hz the emission level is 113 dBpT, which is equivalent to 4.47 mgauss, and at 40 kHz the emission level is 86 dBpT, which is 0.2 mgauss; these values are well below the exposure limits established by Navy policy. Figure 17 illustrates electric field data from the Kaman bus with no emissions above the specified level.

DODGE DAKOTA PICKUP TRUCK

The Dodge Dakota was powered by a 125-hp, ac electric motor and controller supplied by Westinghouse Corporation. It was equipped with 24 12-V lead acid batteries supplied by GNB Battery Technologies. The Dakota utilizes a single-speed transmission and a regenerative braking system. Figure 18 shows a loop antenna 7 cm from the hood of the Dodge Dakota, as well as an electric field antenna 10 m behind the vehicle. Figure 19 shows the electronic components under the hood of the Dakota. Data were taken with the Dakota jacked up and running at 40 mph.

Figure 20 shows the magnetic field data for the Dodge Dakota taken in the open field; the highest spikes above the specified level are between 8 kHz and 50 kHz. At 8 kHz the spike level is 97 dBpT, which is equivalent to 0.71 mgauss according to the conversion factor, and at 40 kHz the level is 88 dBpT, which is equivalent to 0.25 mgauss. Again, these values are well below the exposure limits. Figure 21 shows the electric field data for the Dakota taken in the open field; no spikes above the specified level occur between 9 kHz and 30 MHz.

SOLECTRIA FORCE

The Solectria Force had a high-efficiency, ac induction drive system that features a direct drive, a dc-dc converter, and a regenerative braking system. It was equipped with an 8-hour onboard battery charger and with sealed, maintenance- free lead acid batteries. The system power for the Solectria Force was 42 kW. The vehicle was tested in the open field, jacked up and running at 35 mph. In the screen room, the Force was running unloaded at 25 mph. Figure 22 shows the Solectria Force in the screen room with the 41-in. stub antenna 1 m in front of the

Figure 13. Hybrid Electric Transit Bus in Open Field

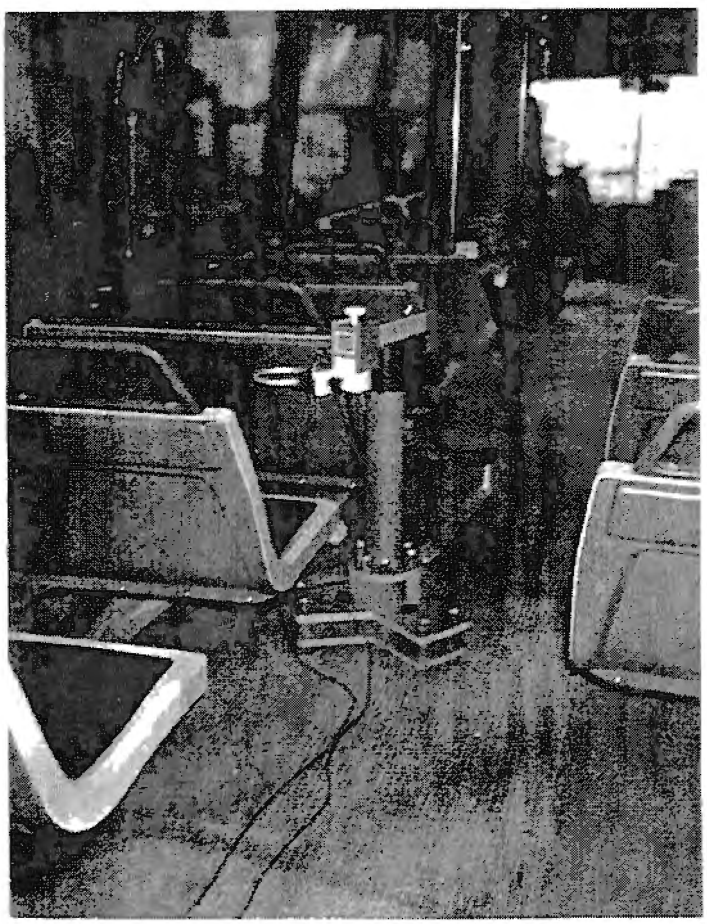


Figure 14. B Field Measurements Taken Inside the Bus

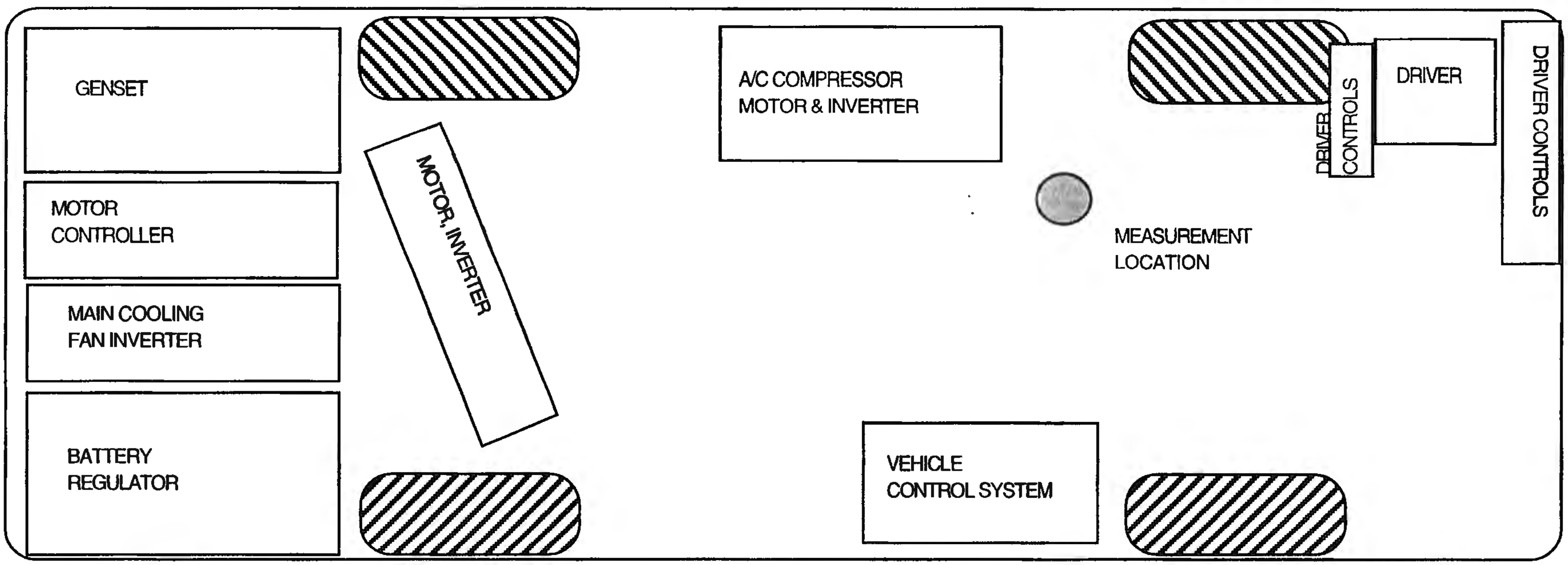


Figure 15. Layout of Electrical Components in the Bus

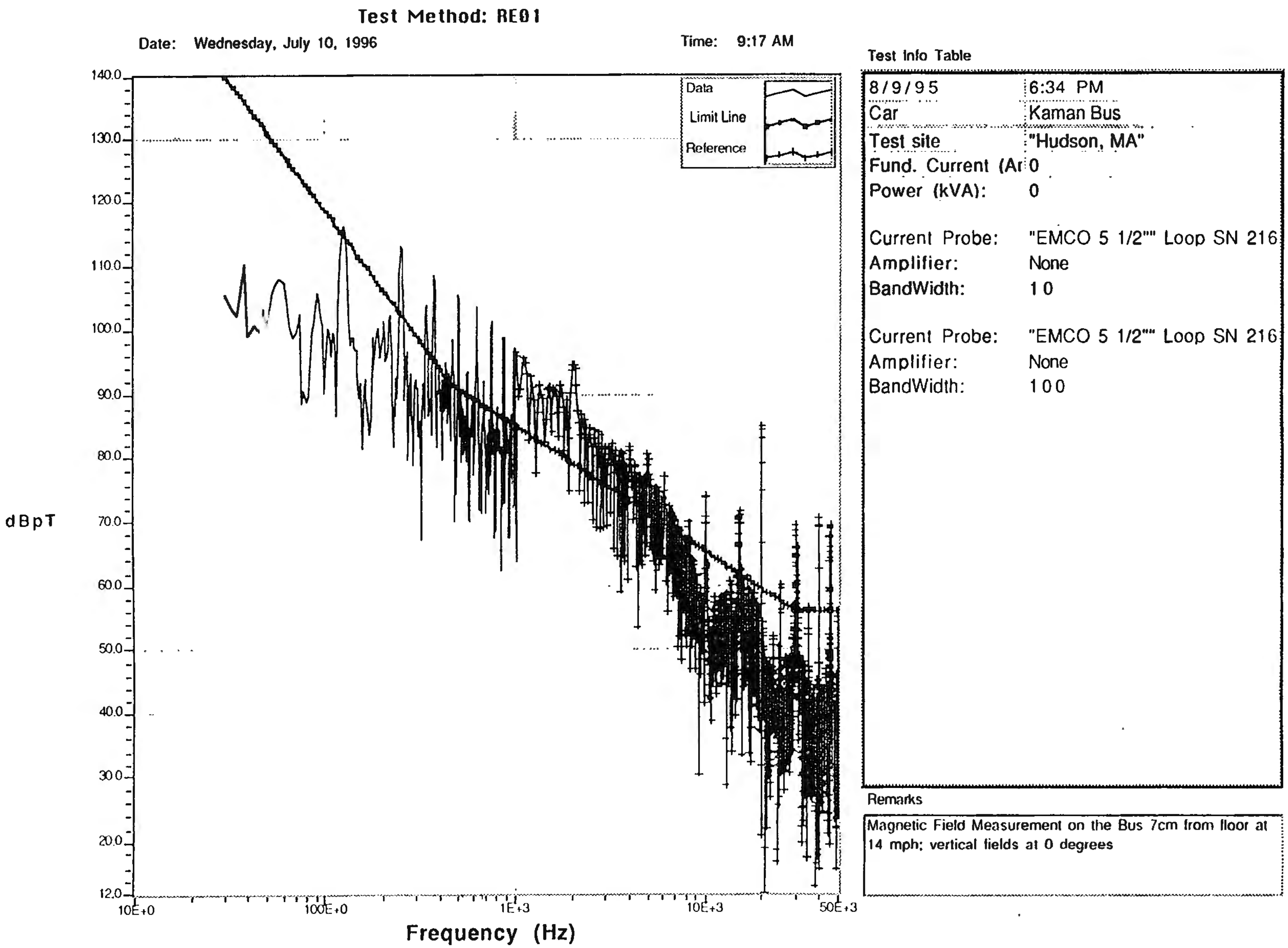
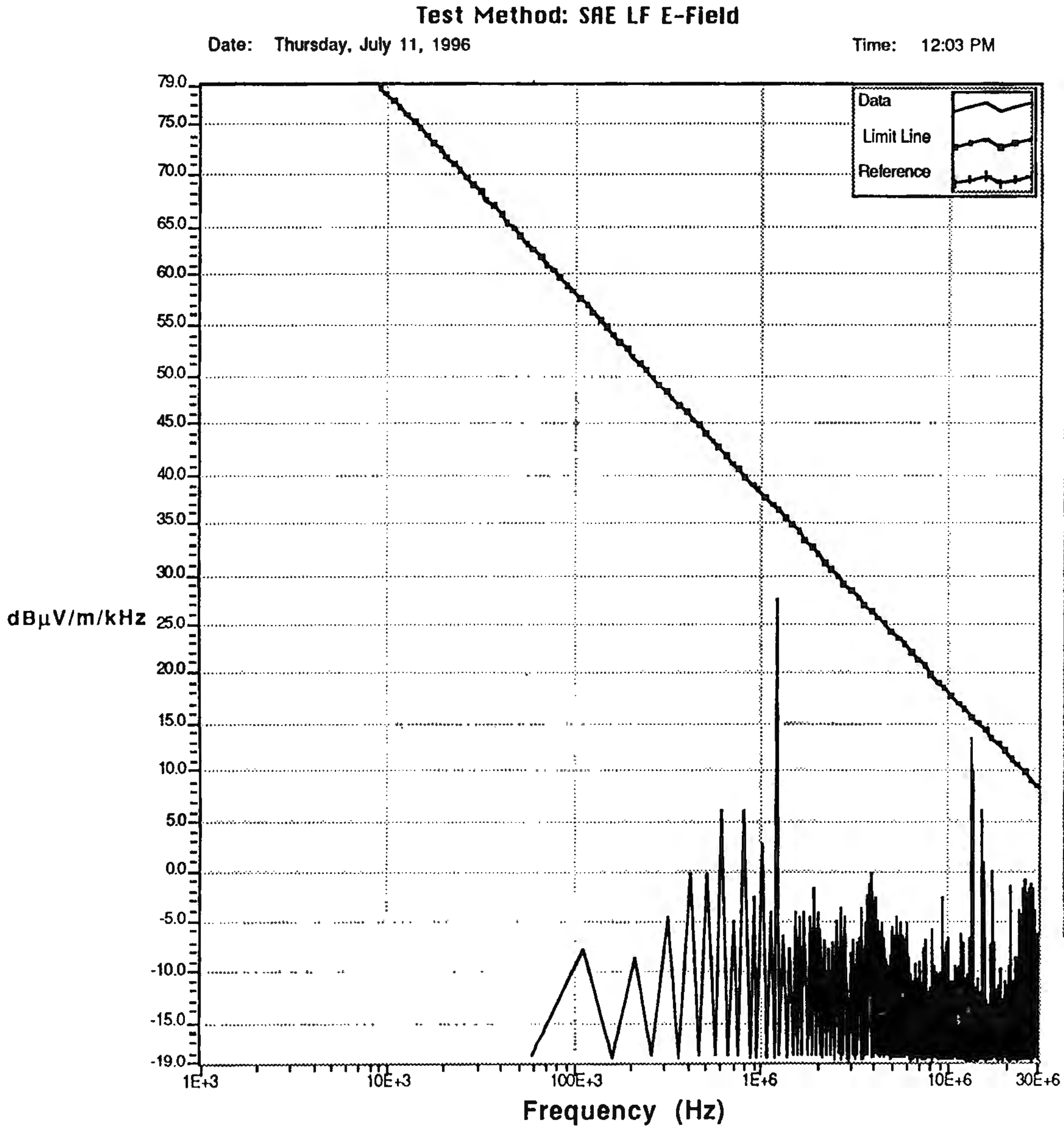


Figure 16. Hybrid Electric Bus in Open Field, B Field Measurements Taken 7 cm from the Floor



Test Info Table

8/17/95	2:11 PM
Car	Kaman Bus
Test site	Hudson, MA
	parking lot
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	BB Active MP SAS-200/550
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurements taken at 1m from behind the bus at Idle condition with antenna phasing Vertical Polarization

Figure 17. Hybrid Electric Bus in Open Field, E Field (0.009-30 MHz) Taken 1 m from Behind in the Idle Condition

Figure 18. Dakota Truck in Open Field, B Field Measurement

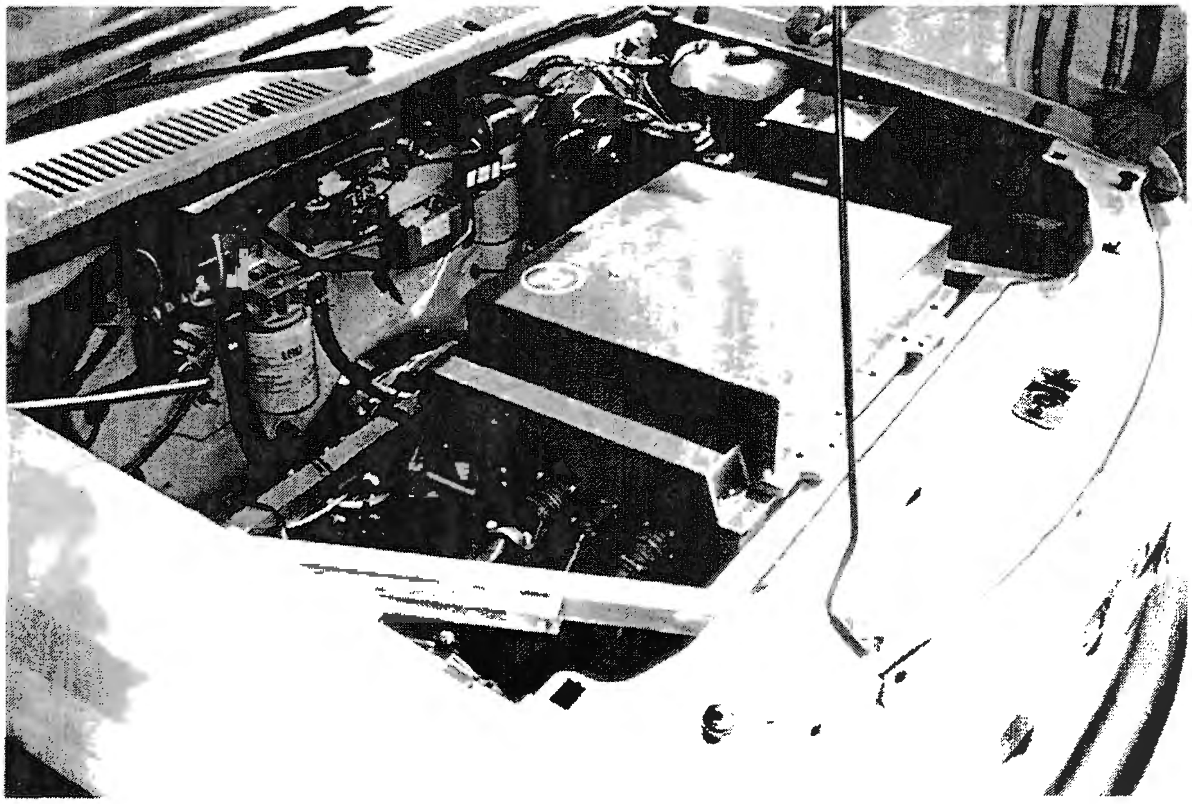
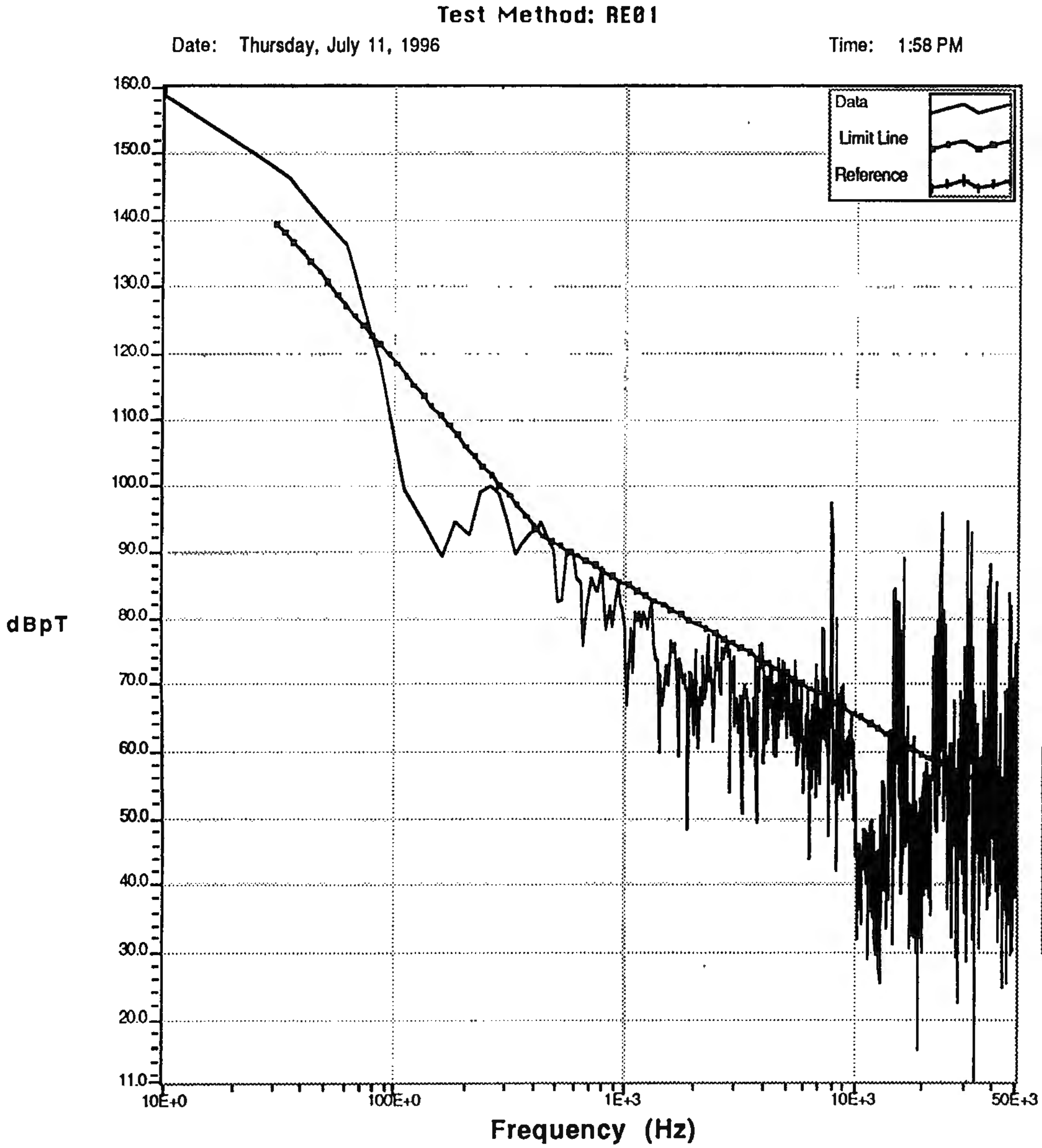


Figure 19. Electronic Components Under the Hood



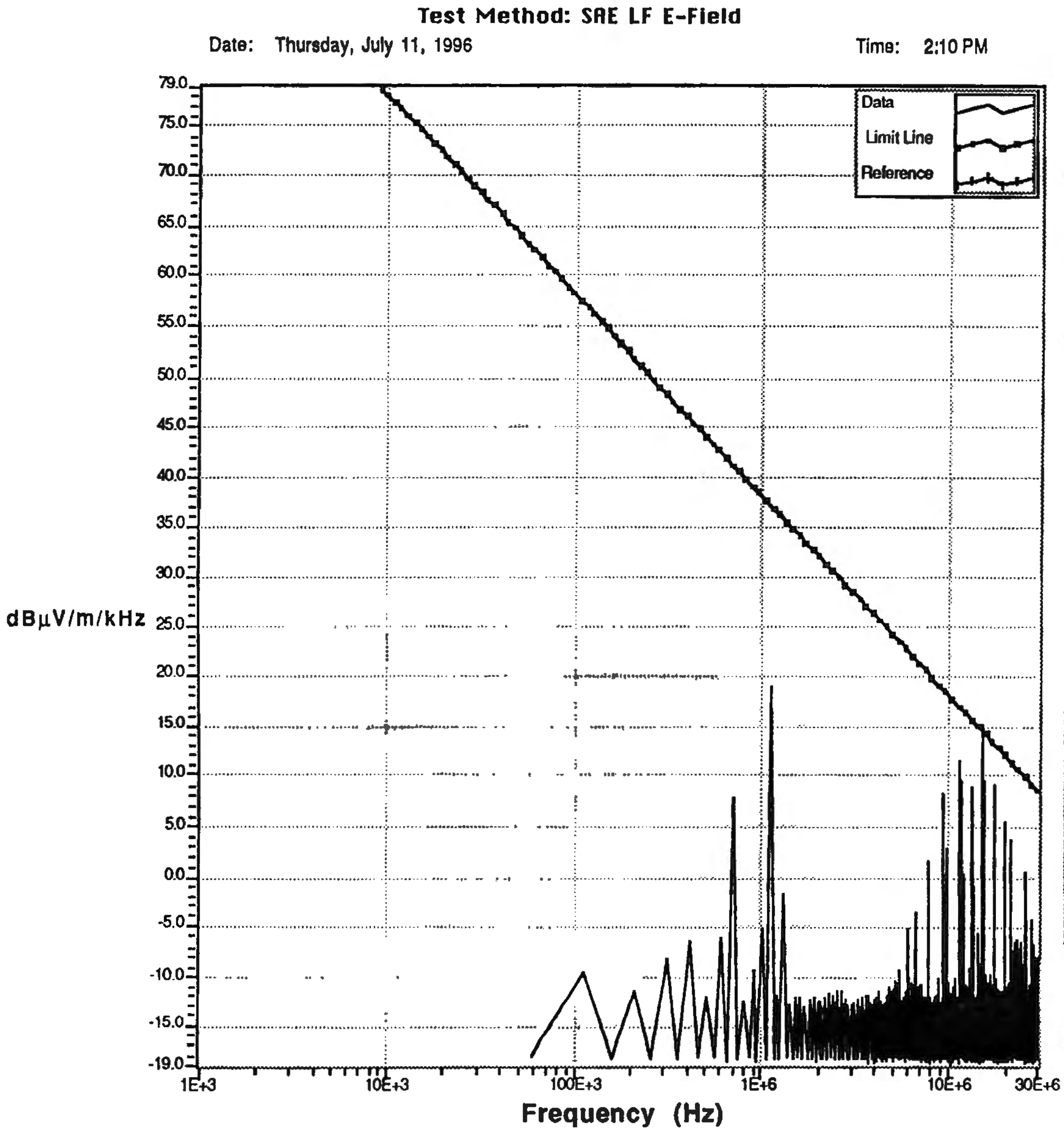
Test Info Table

8/23/95	2:18 PM
Car	Robins AFB DD2
Test site	Robins AFB, Training Site
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	EMCO 5 1/2" Loop SN 2163
Amplifier:	None
BandWidth:	100

Remarks

Magnetic Field Measurements with Loop antenna located at 7 centimeters from the passenger side of the car. Car jacked up and running 40 mph

Figure 20. Dodge Dakota Vehicle in Open Field, B Field Measurements Taken 7 cm from the Passenger's Side



Test Info Table

8/22/95	5:02 PM
Car	Robins AFB DD2
Test site	Robins AFB, Training Site
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	BB Active MP SAS-200/550
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurements with antenna located at 1 meter from the front side of the car and 1 meter up from the ground. Car jacked up and running 30 mph

Figure 21. Dodge Dakota Vehicle in Open Field, E Field (0.009-30 MHz) Taken 1 m from the Front Side

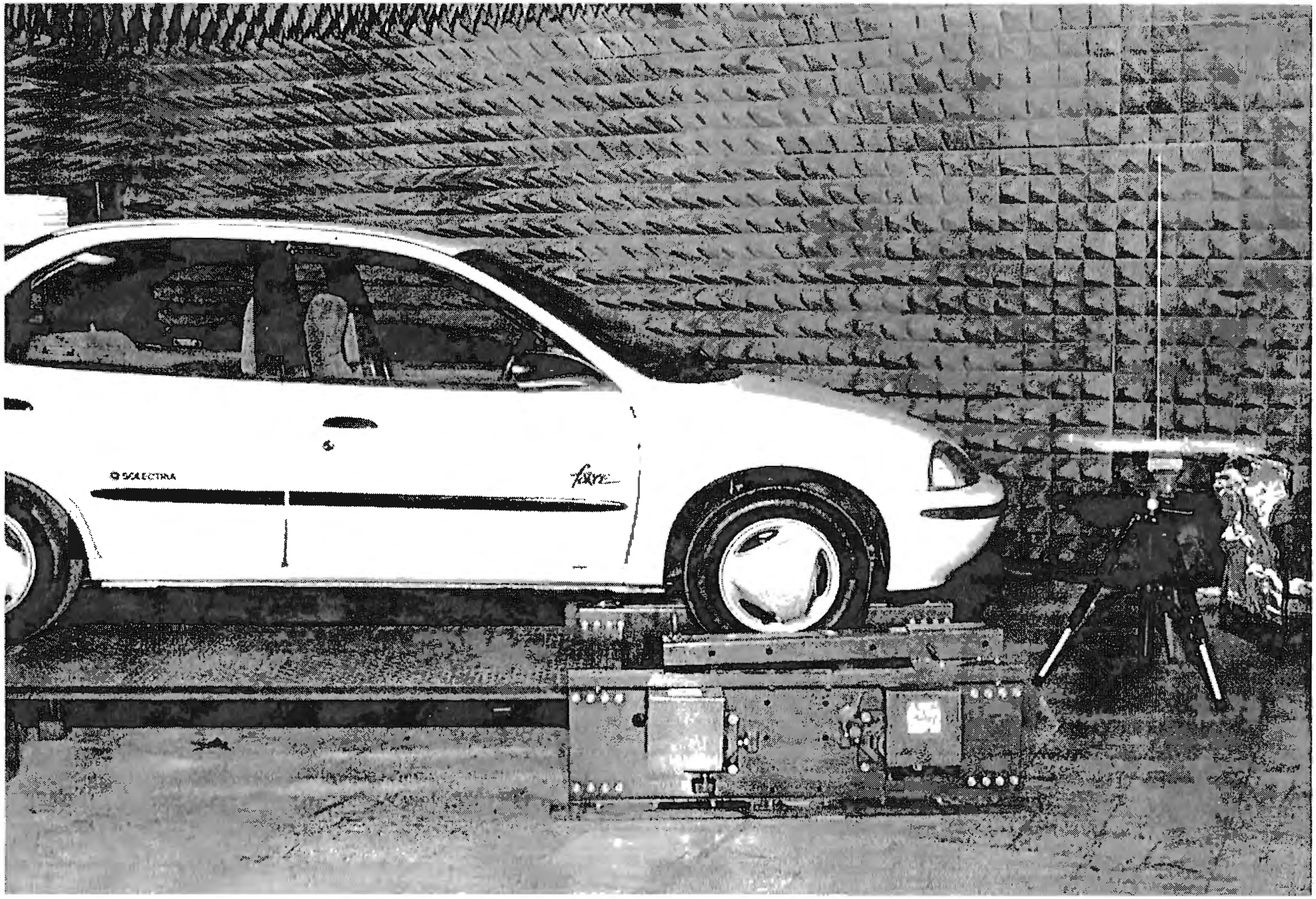


Figure 22. Solectria Force Car in Anechoic Chamber Test

vehicle. Figure 23 shows the magnetic open field emission spectrum for the Solectria Force. The magnetic field emissions were above the limit, but were identified as being attributable to the measured EM ambient. Figure 24 shows the corresponding magnetic field emission data for the Solectria Force measured in the screen room. Again, the open field measurements and the screen room measurements are shown to be in agreement. Similarly, figures 25 and 26 show the electric field data for the Solectria Force taken in the open field and screen room, respectively; no emissions were over the limit, but were identified as being attributable to the measured EM ambient (see figure A29).

SELECTED SOLECTRIA CONTROLLERS

Figure 27 shows the magnetic field data for a typical motor controller measured at NUWC's screen room facility. From these data one may suspect that the ac controller is one of the units that causes most of the EMI emissions from the electric vehicles. Such emissions are mostly created by the harmonics of the fundamental operating frequency of the dc conversion controller.

Figures 28 and 29 show the conducted emissions data of an ac controller without and with an inexpensive EMI fix, respectively. An improvement of 10 dB was observed when a capacitor filter was installed in the power lines of the ac controller.

GEO METRO ICE

For comparison purposes a preconversion Geo Metro with an internal combustion erngine (ICE) was tested in the Dayton T. Brown screen room. The ICE was running unloaded at 25 mph during the test. Figure 30 shows the Geo Metro in the screen room with the double ridge guide antenna positioned 1 m in front of the vehicle. No magnetic field emissions were observed that exceeded the MIL-STD limit line at 7 cm from the vehicle. This result is not surprising because the ICE vehicle has no high-current sources comparable to those in the EVs. Figure 31 shows a typical magnetic field spectrum of the emissions from the drivers side of the ICE vehicle. Figure 32 shows the electric field emissions at 1 m from the driver's side of the vehicle. Note the wide-band radio frequency (RF) emissions typical of an ICE. These wide-band emissions were caused by impulsive noise generated by the sparks associated with combustion.

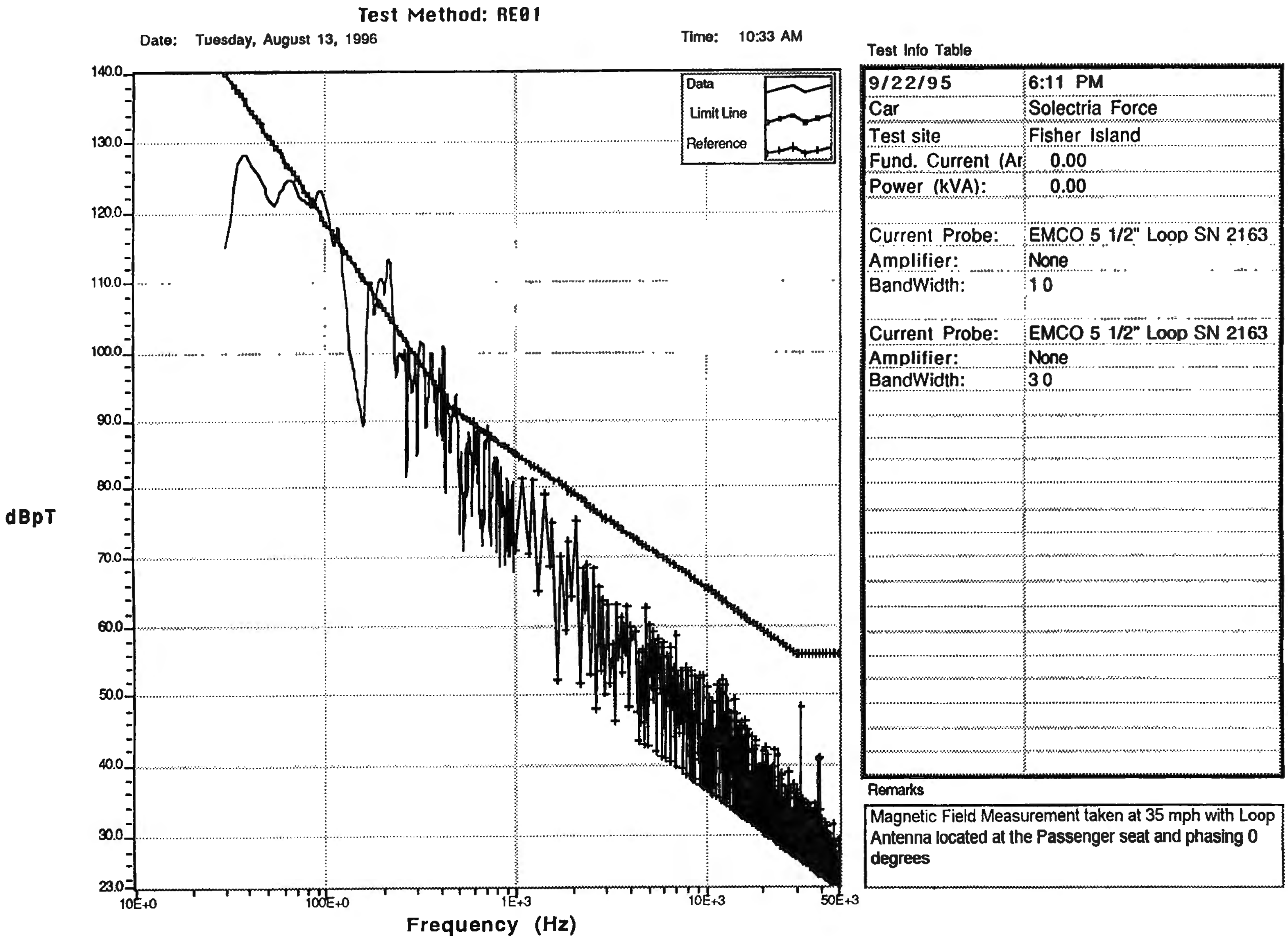


Figure 23. Solectria Force Vehicle in Open Field, B Field Measurements Taken at the Passenger's Seat

Dayton T. Brown Inc.

MIL-STD-461C RE01 CLASS A3

Date :	09/20/95	Time :	08:21:08.79	EMC-11 SETTINGS		SPECS
Technician :	V.Mirkov V.M	Job Number :	409175-00-000	Detector	Peak	1) MIL-STD-461C RE01
Customer:	McLaughlin Research	Test Number :	9175017	Bandwidth	Per Table	2)
Test Item :	SOLECTRIA	Sensor Loc. :	Passenger side	Impedence	50 Ohm	3)
Mode of Op. :	Drive	Sensor Pol. :		RF Atten.	60 dB	4)
Serial No. :	PROTOTYPE	Ext. Atten. :	0 dB	High Pass	16 Hz	R. Tambuillo
				Low Pass	50 kHz	
				Output	IF	

Comment :

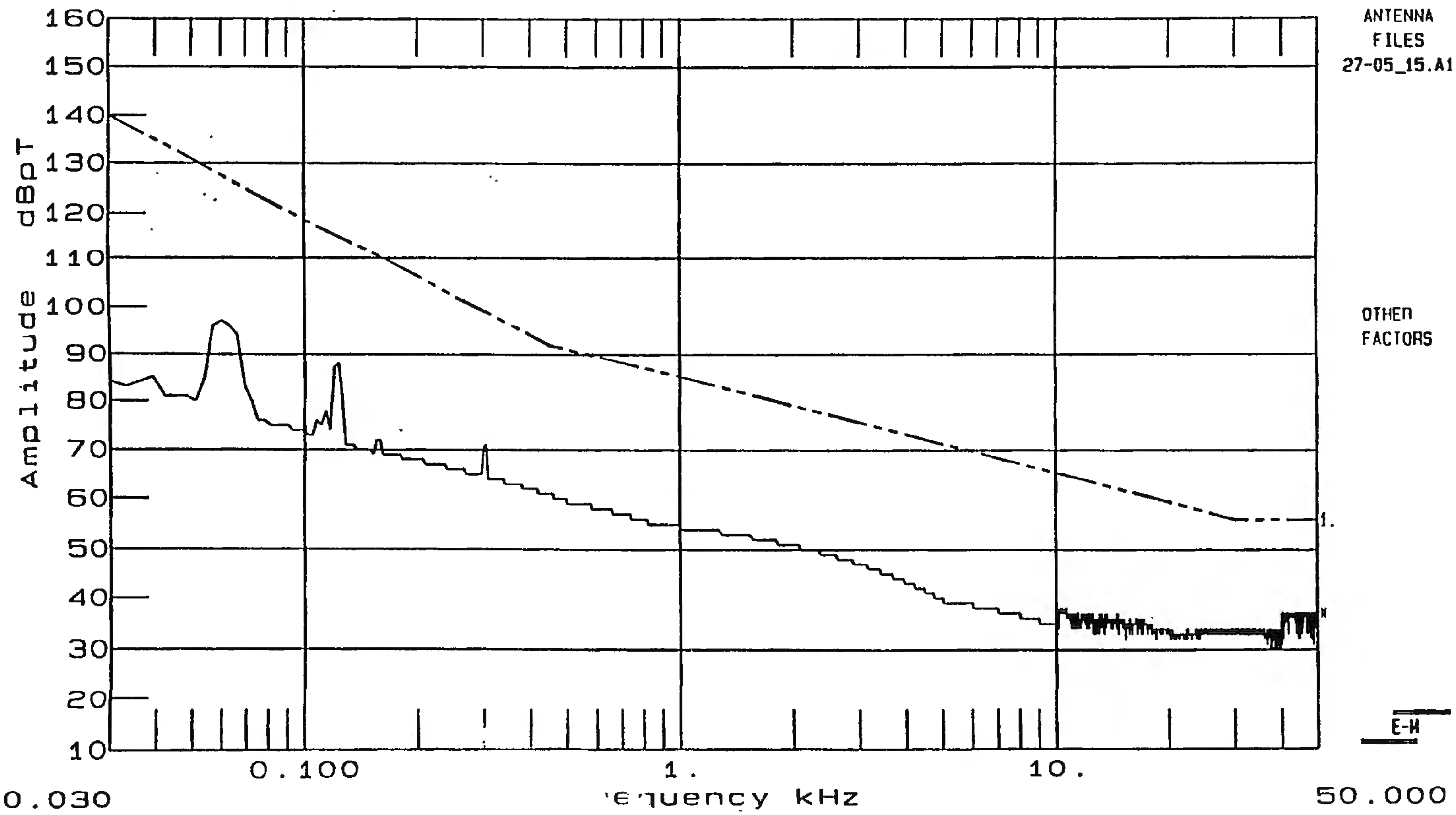
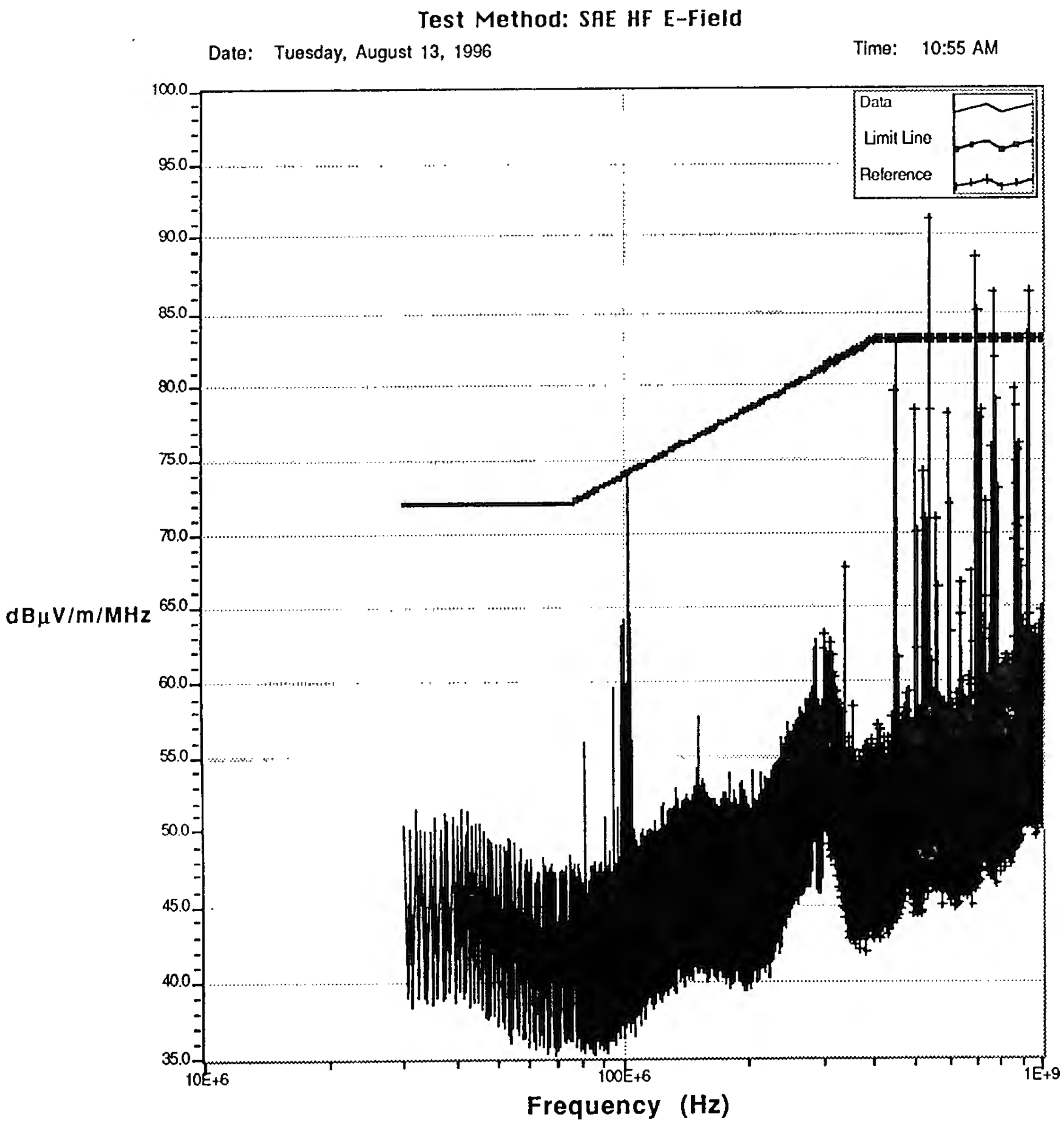


Figure 24. Solectria Force Vehicle in Anechoic Room, B Field Measurements Taken at the Passenger's Seat



Test Info Table

9/22/95	4:57 PM
Car	Solectria Force
Test site	Fisher Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	10000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	10000

Remarks

Electric Field Measurement taken at 35 mph condition with car jacked up and antenna located at 10 m from the Front section of the car.
Antenna phase is Horizontal Polarization

Figure 25. Solectria Force Vehicle in Open Field, E Field (30-1000 MHz) Taken 10 m from the Front Side

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/19/95	Time :	17:53:48.09	EMC-30 SETTINGS		SPECS
Technician :	C. TREADWELL	Test Equip. :	409175-00-000	Detector	Peak	1) J551 @ 1 Meter
Test Method :	McLaughlin Research	Test Number :	9175040	Bandwidth	Per Band	2)
Equipment :	Solectria	Sensor Loc. :	1m IN FRONT	Dwell	10 msec.	
Mode of Op. :	DRIVE	Sensor Pol. :	HORIZONTAL	RF Atten.	0 dB	
Serial No. :	Prototype	Ext. Atten. :	0 dB	IF Atten.	0 dB	

Comment : UNLOADED

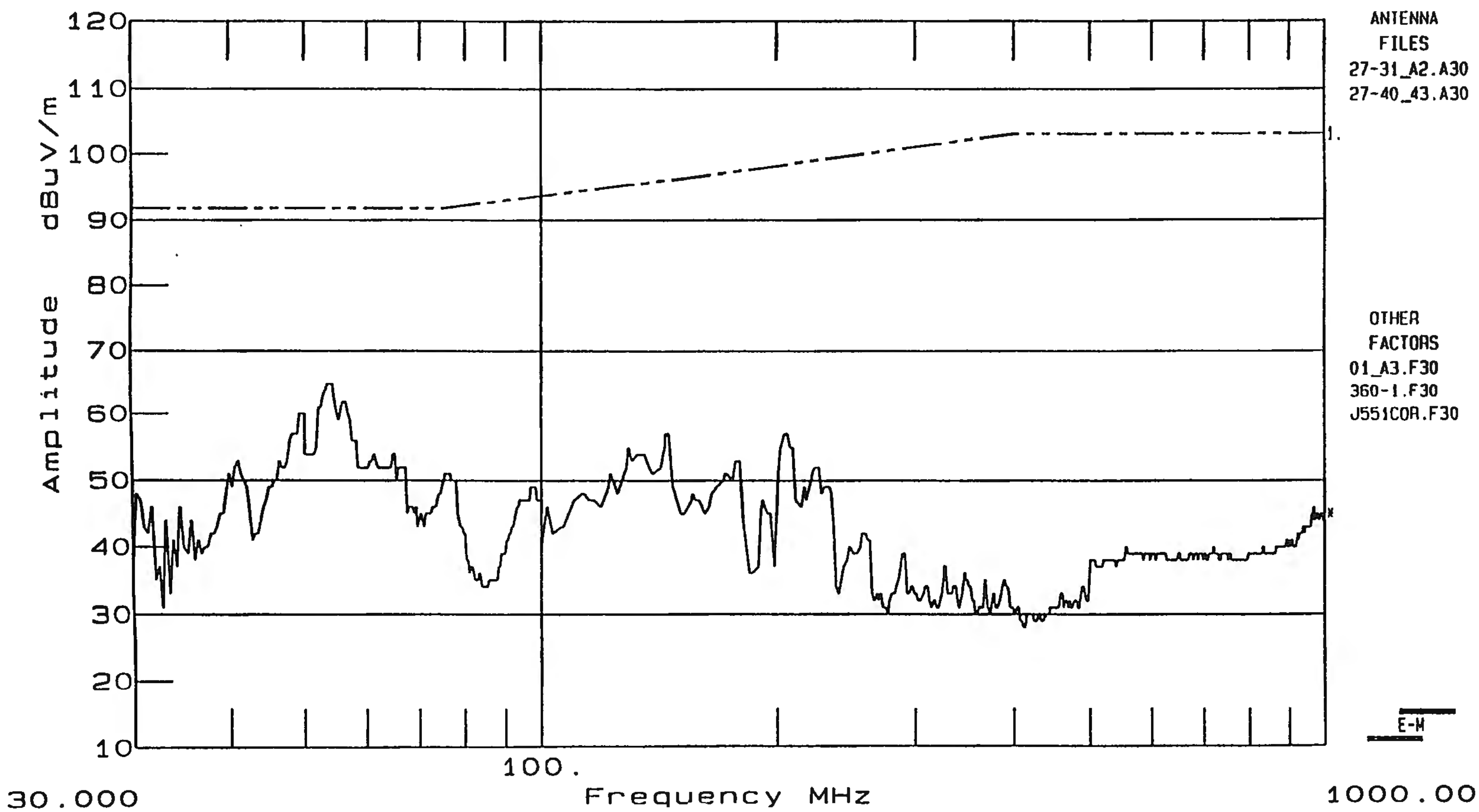


Figure 26. Solectria Force Vehicle in Anechoic Room, E Field (30-1000 MHz) Taken 1 m from the Front Side

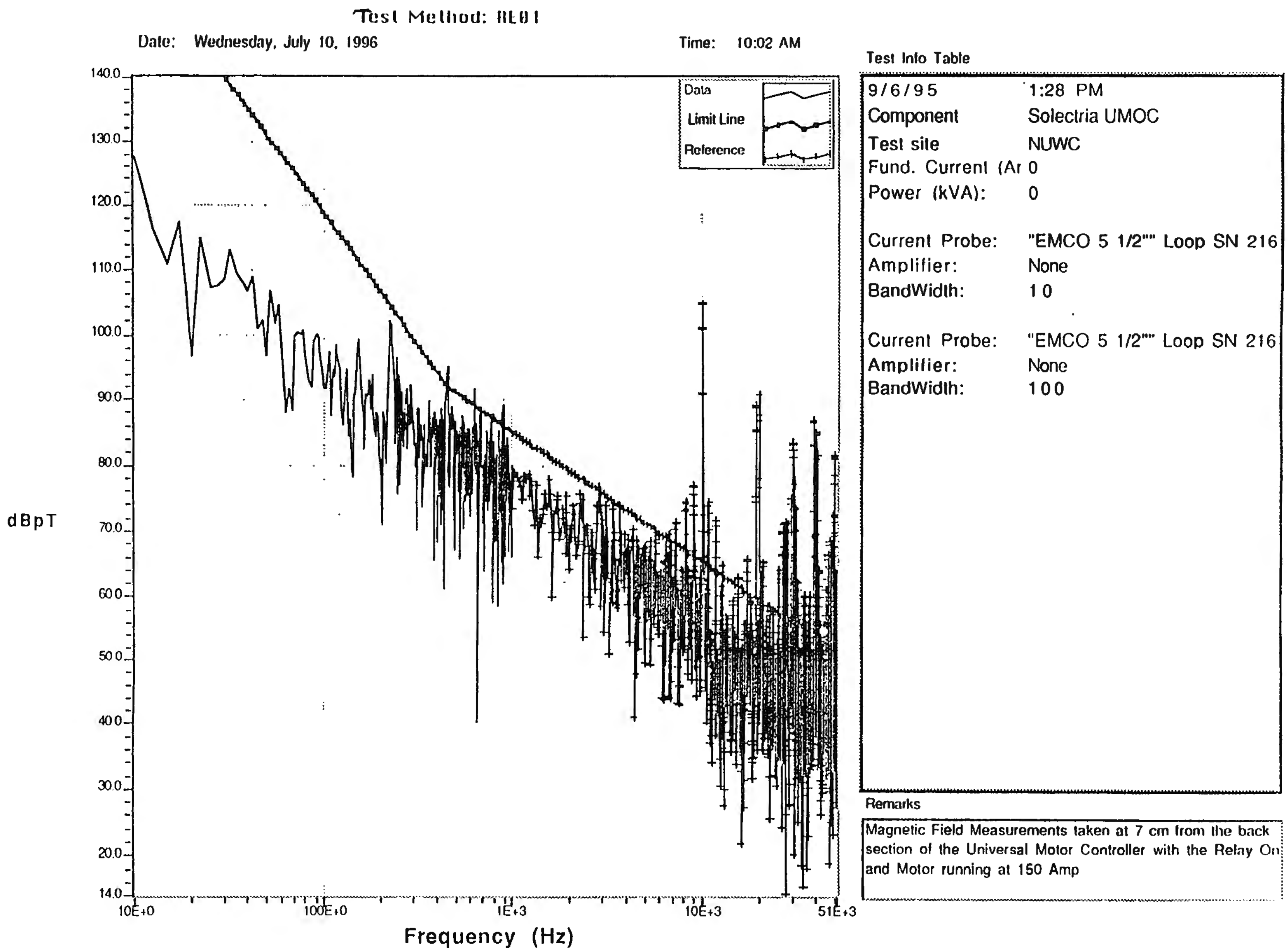


Figure 27. Solectria Motor Controller in Anechoic Room, B Field Measurements Taken 7 cm from the Back Side

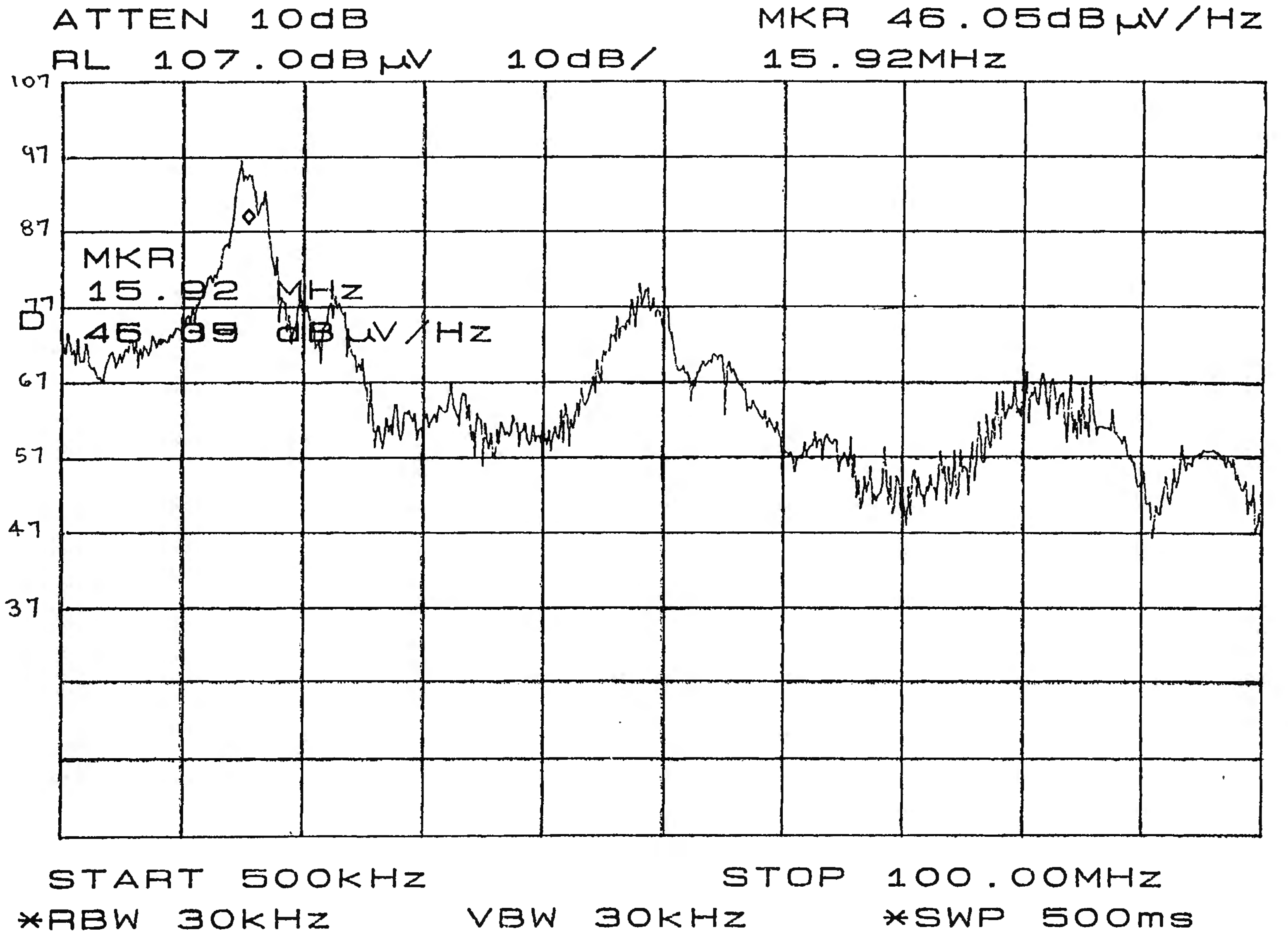


Figure 28. Solectria Motor Controller Conducted Emission in Anechoic Room Without an EMI Fix in the Power Lines

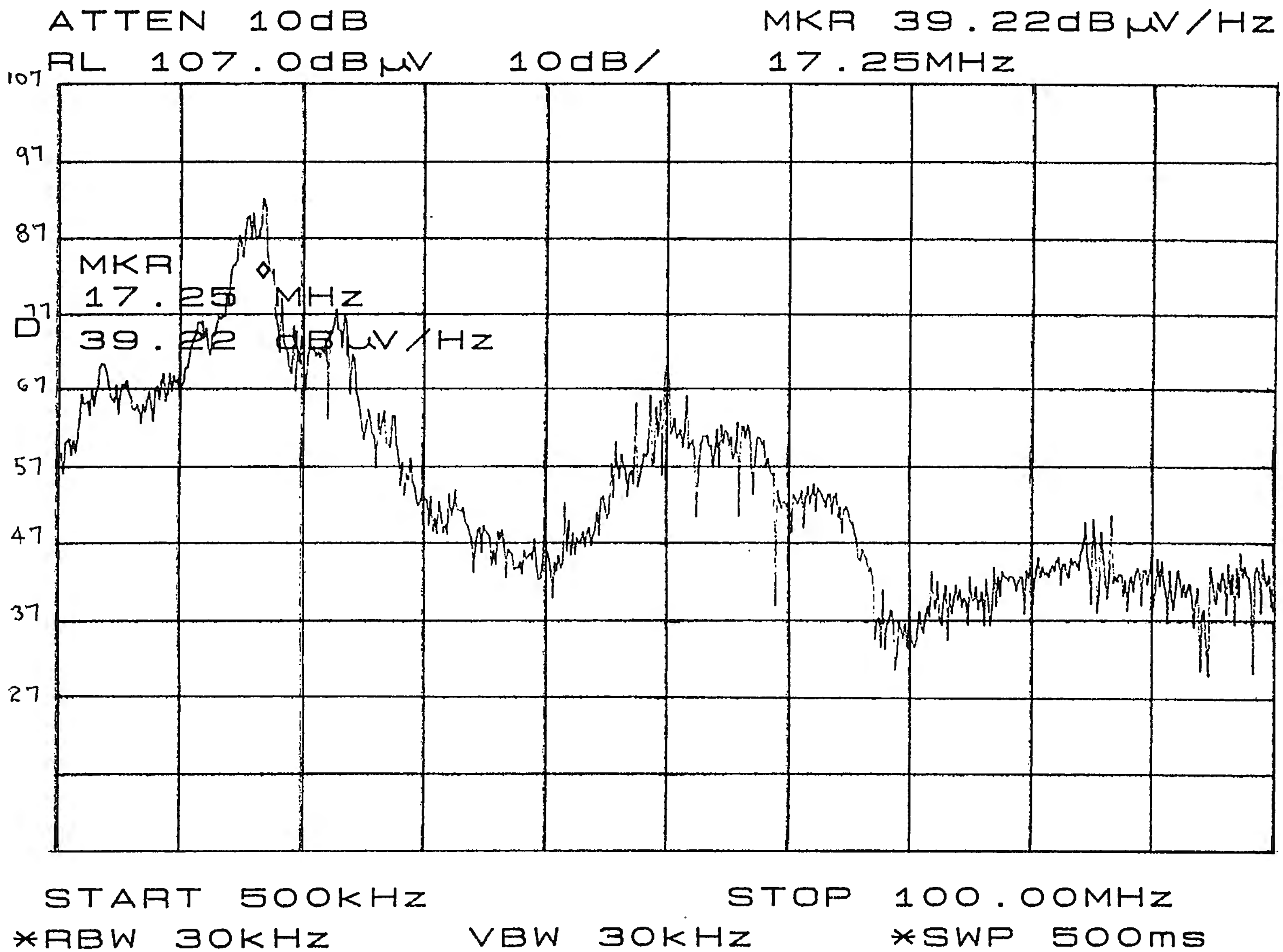


Figure 29. Solectria Motor Controller Conducted Emission in Anechoic Room With an EMI Fix in the Power Lines

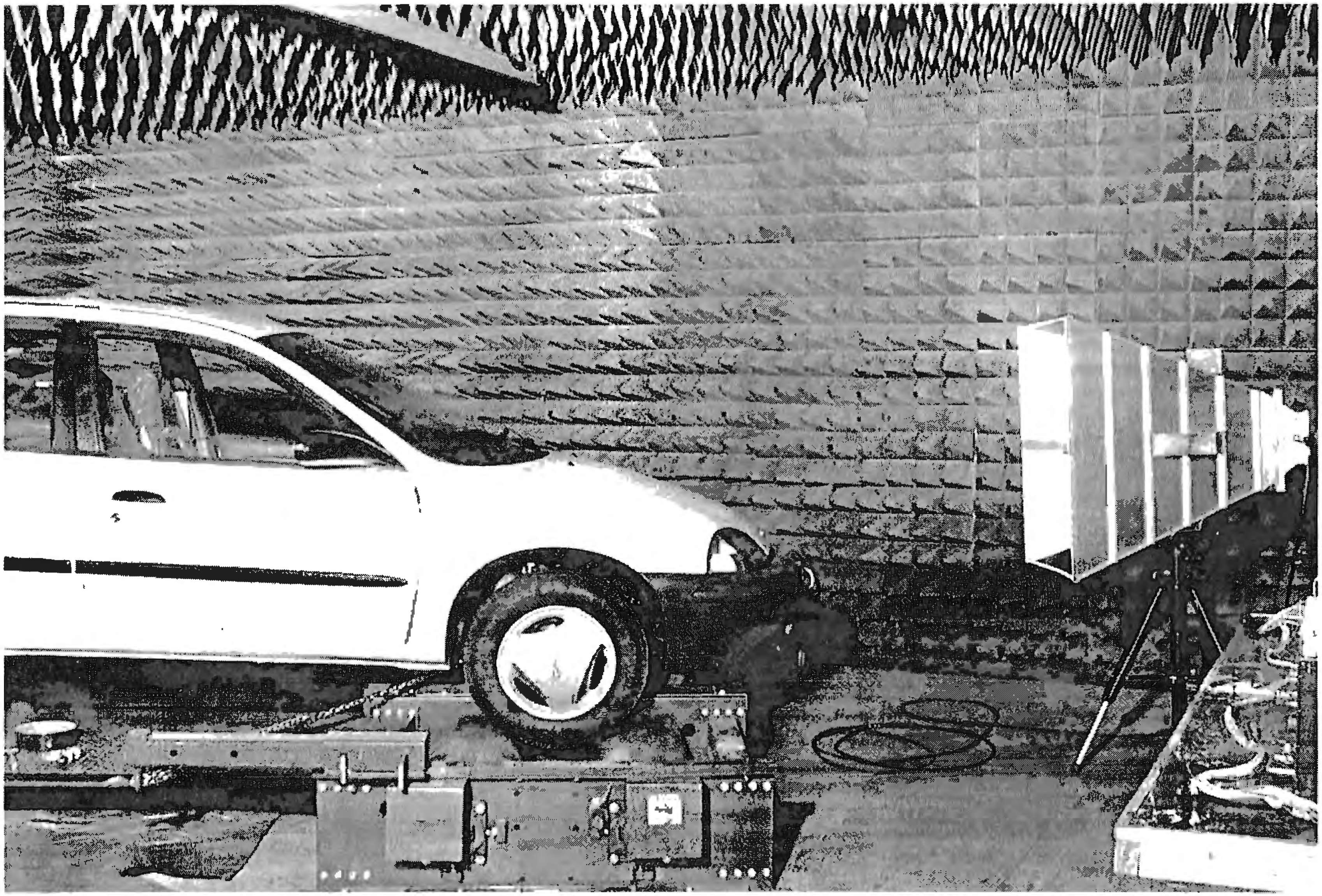


Figure 30. Solectria ICE Car in Anechoic Chamber Test

Dayton T. Brown Inc.

MIL-STD-461C RE01 CLASS A3

Date :	09/20/95	Time : 14: 32: 49.31	EMC-11 SETTINGS		SPECS	
Technician :	V.Mirkov *V.M.*	Job Number : 409175-00-000	Detector	Peak	1) MIL-STD-461C RE01	
Customer:	McLaughlin Research	Test Number : 9175022	Bandwidth	Per Table	2)	
Test Item :	Gas Powered car	Sensor Loc. : Driver side	Impedence	50 Ohm	3)	
Mode of Op. :	Drive	Sensor Pol. :	RF Atten.	60 dB	4)	
Serial No. :	PROTOTYPE	Ext. Atten. : 0 dB	High Pass	16 Hz		
			Low Pass	50 kHz		
			Output	IF		

Comment :

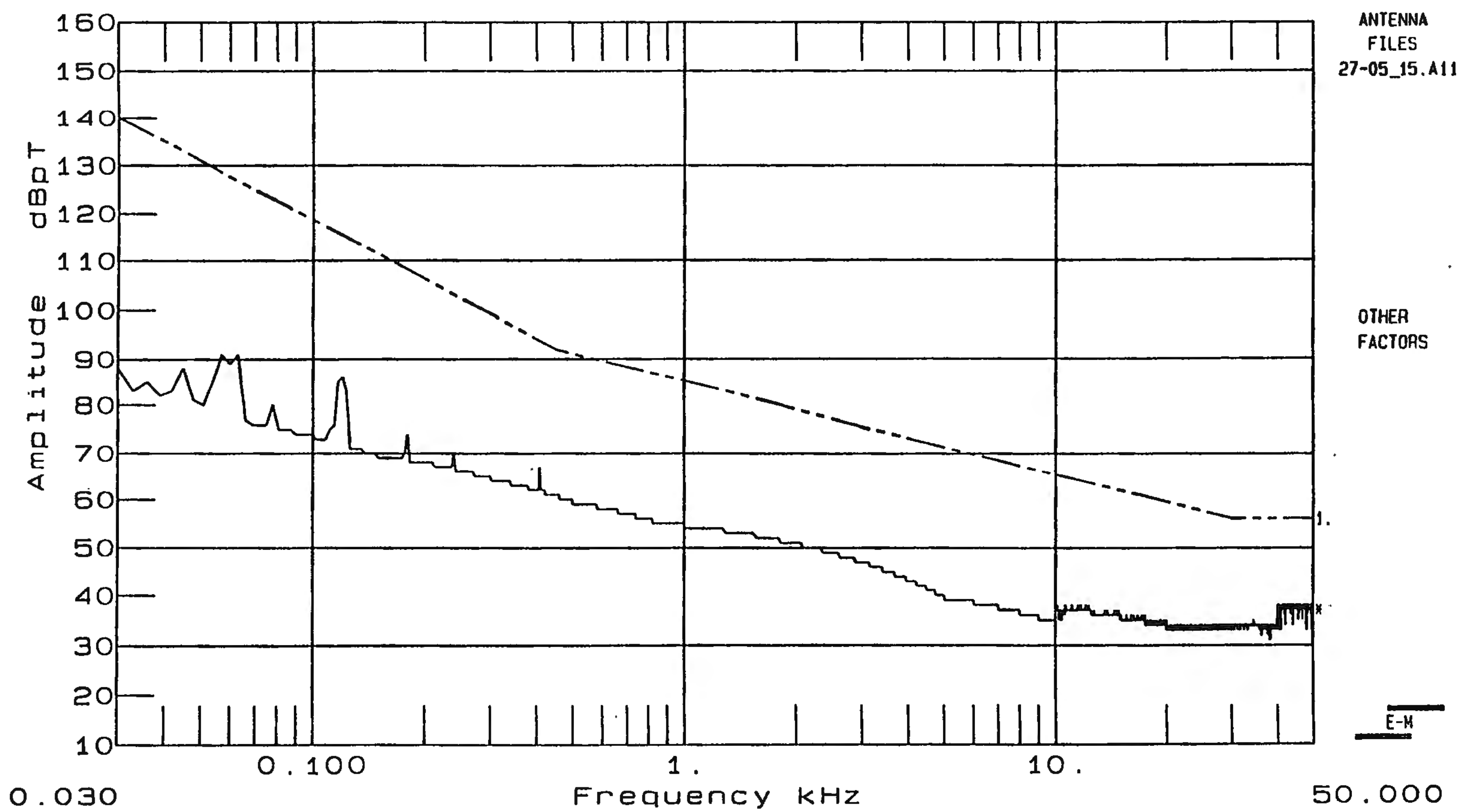


Figure 31. Solectria ICE Car in Anechoic Chamber, B Field Measurements Taken at the Driver's Side

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/20/95	Time :	18:25:02.81	EMC-30 SETTINGS		SPECS
Technician :	V.Mirkov V.M.	Job Number	: 409175-00-000	Detector	Peak	1) J551 @ 1 Meter .014-30 MHz
Customer	: McLaughlin Research	Test Number	: 9175054	Bandwidth	Per Band	2)
Test Item :	Gas powered car	Sensor Loc.	: DRIVERS SIDE	Dwell	10 msec.	
Mode of Op.	: Drive	Sensor Pol.	: VERTICAL	RF Atten.	0 dB	
Serial No. :	2C1MR5292S6783748	Ext. Atten.	: 0 dB	IF Atten.	0 dB	DATA FILE : 9175054.D31

Comment : Unloaded 25Mph

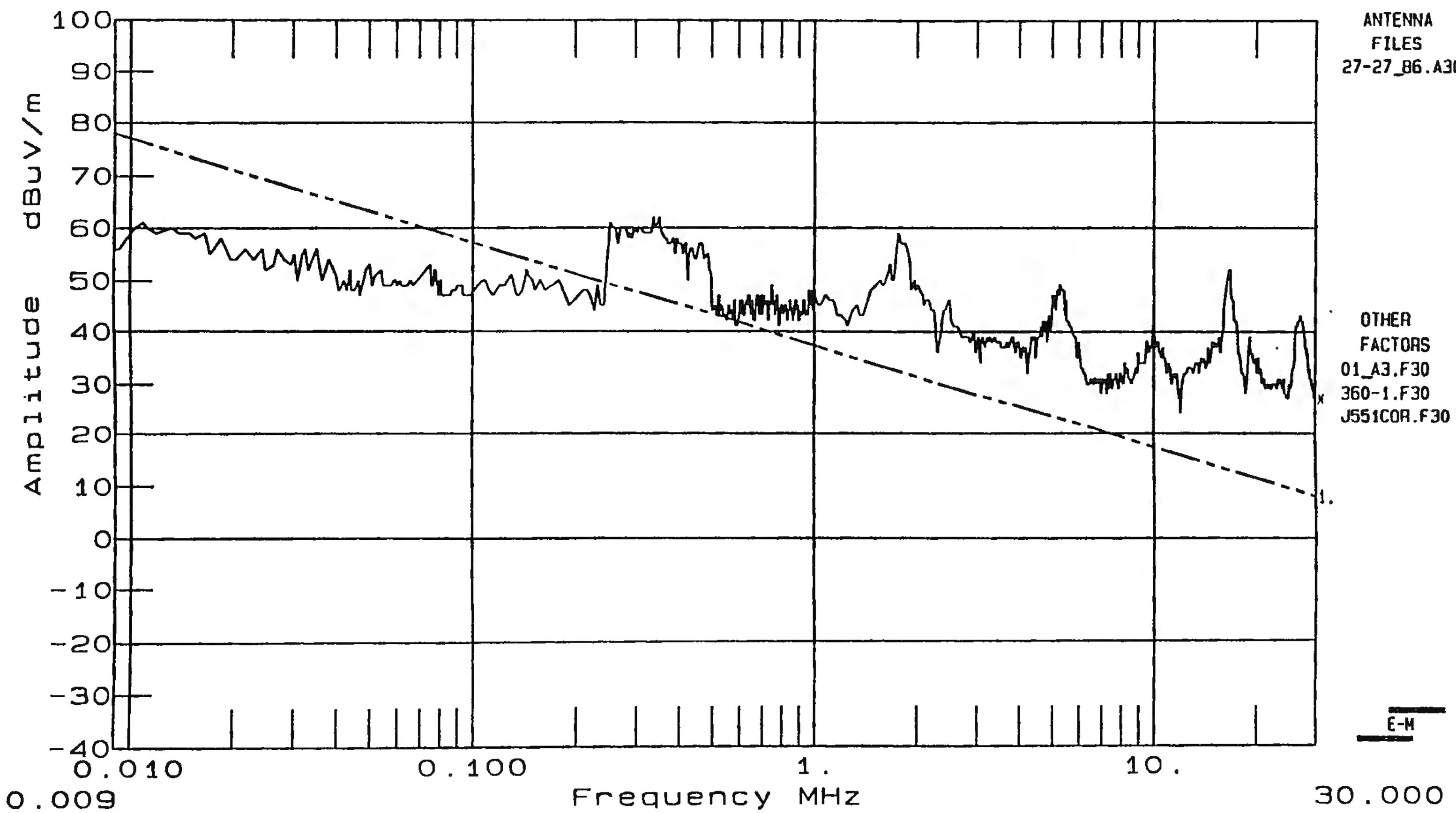


Figure 32. Solectria ICE Car in Anechoic Chamber, E Field (0.009-30 MHz) Taken at the Driver's Side

TEST RESULTS AND DISCUSSION

The data collected from all the vehicles are plotted in the appendix. Each data plot contains the data collected from the test and the corresponding SAE J551 electric field limit line and the MIL-STD 461C magnetic field limit line. The MIL-STD 461C limit line is the standard limit used by the military and is incorporated into the software to generate the data plots from EMI sources taken at 7 cm with a loop antenna. The MIL-STD limit line was used because the SAE does not have a low-frequency magnetic field specification limit. Based on the MIL-STD specification, one may infer that any magnetic field emissions coming from the electric vehicles will be under consideration if they degrade the performance of other vehicles or systems located within a distance of 7 cm. However, a 7-cm distance will not be met except between internal components. Furthermore, the 7-cm distance can be used to troubleshoot the electric vehicles and locate the highest radiating magnetic sources. Therefore, taking measurements at 1 m from the electric vehicles or relaxing the specification limit by 10-20 dB will be a more realistic approach for evaluating the magnetic field emissions radiated from the EVs.

Electric field emissions were measured at 1 m and 10 m from each of the vehicles tested. No electric field emissions were above the SAE limit line that could not be identified as corresponding to background emissions. This result was not unanticipated because electric vehicles are essentially current sources that have associated magnetic fields. ICEs, on the other hand, are electric field radiators because of their transient behavior (attributed to spark plugs).

OPNAVINST 5100.23D [6] establishes Navy policy for personnel exposure to radio frequency radiation (RFR); it identifies permissible RFR exposure limits in terms of field intensity and power density for personnel in unrestricted areas, which includes shore-based installations. Table 4 is a summary of the Navy limits for personnel and ordnance under various conditions. For magnetic fields, no personnel exposure limit below 10 kHz is specified. The International Radiation Protection Association (IRPA) recommends that maximum exposure to power line fields (60 Hz) is 5 G (174 dB pT). The highest 60-Hz field observed in the tests reported in this document was 120 dB re pT, which corresponds to 10 mG (see figure 9). The 60-Hz component observed here is probably due to the dynamometer. For frequencies between 10 kHz and 100 kHz, IRPA recommends an exposure limit of 20 mG. The highest magnetic field amplitude of 1.2 mG observed in that range was on the Dodge Dakota at 8 kHz. Other frequencies observed on the Dakota were at 24 kHz, with an amplitude of 1.0 mG, and at 30 kHz, with an amplitude of 1.0 mG (see figure 20). These levels are an order of magnitude below the recommended exposure limit. Note that the levels being reported are measured levels, and they are being compared with published recommended exposure limits. No inference should be drawn as to the safety of the potential exposure of an individual to the observed magnetic fields in relation to the recommended exposure limits.

For electric fields the minimum unrestricted exposure limit from 30-300 MHz is 63.2 V/m (nearfield) or 1 mW/cm^2 (farfield). At a 1-m range the highest observable electric field was from the Kaman Bus, an amplitude 20 mV/m at 1.1 MHz. This highest measured level is six orders of magnitude below the recommended level of exposure. Therefore, the generated electric field

Table 4. Navy Reference Exposure Limits

EM Source	Personnel (OPNAVINST 5100.23D)	Ordnance (NAVSEA OD 30393 and MIL-STD-1385B)
dc **Magnetic Field** (DOD-STD-1399 Section 070 (20 G))	No OPNAVINST 5100.23D requirements exist. The following information is based on the most conservative guidelines established by the international scientific community: _ For persons with pacemakers, ferromagnetic implants, implanted electronic devices or prosthetic implants, maximum safe exposure is 5G. _ No action required for all others because the most conservative guidelines (Stanford) show no health concerns for whole body or head exposure to flux densities less than 200G for extended periods.	No hazards of electromagnetic radiation to ordnance(HERO) requirements for dc magnetic fields. Appropriate precautions will be followed if ordnance components are subjected to dc magnetic field susceptibility testing.
Low-Frequency **ac** **Magnetic Field** (MIL-STD-461 RS01, RS02, RS101)	No OPNAVINST 5100.23D requirements exist below 10 kHz. Limit from 10-100 kHz is 20mG, which exceeds the highest MIL-STD limit (tailored-NSSN RS101 is 12.5 mG) by a minimum 4 dB in that frequency range. IRPA interim guidelines issued in 1990 for human exposure to 50/60-Hz magnetic fields are based on biological effects (induced body currents). Maximum for occupational whole-day exposure is 5 G range measurement system (RMS), which is ~2 dB less than the RS101 limit of 5.62 G peak.	No HERO requirements for low-frequency magnetic fields. Appropriate precautions will be followed if ordnance components are subjected to EMI susceptibility testing.
Electric Field (MIL-STD-461 RS03 (1 V/m) RS103 (5 V/m))	No threat to personnel safety. Even field strengths outside the shielded room are well below the lowest OPNAVINST 5100.23D limit of 63.2 V/m.	No minimum separation distance required during electric field susceptibility testing with shielded room door closed (need 40-dB shielding effectiveness; shielded room spec is 120 dB for electric fields and plane waves). Otherwise: _ Maintain a minimum distance of 50 m from the antenna for HERO UNSAFE/UNRELIABLE ordnance (includes disassembled ordnance and maximum coupling). _ Maintain a minimum distance of 5 m from the antenna for HERO SUSCEPTIBLE ordnance.

levels in the electric vehicles are not of sufficient magnitude to present a threat to the safety of the drivers or passengers.

CONCLUSIONS

To date, the data collected have shown that the open-field measurement technique is valid and gives measurements that are equivalent to similar measurements made in special screen room facilities. The cost of open-field measurement is typically an order of magnitude lower than their screen room equivalents. The only constraint that open-field measurements impose is that the background noise be at least 20 dB below the expected measurement levels. This condition can be met by choosing areas that are electrically quiet, i.e., areas that are away from manmade sources of electrical noise. The open-field condition is verified at each measurement site by recording a sample of background noise before beginning measurements on the vehicle.

The major sources of radiation from the electric vehicles considered were the motor controllers, dc to dc converters, power steering motors, brake vacuum pumps, distribution boxes, cable harnesses, and drive motors. Therefore, these devices should be considered for EMI abatement techniques such as filtering, gasketing, shielding, and rerouting of components or cables to meet the requirements and to avoid the potential risk of affecting the performance of other vehicles or systems. Measurements taken on the Solectria controllers show that simple and inexpensive EMI techniques can reduce magnetic field levels by 10 dB.

Measured field levels in most cases were below the specified limit line. In cases where field levels exceeded specified limits, measured electric and magnetic field levels were compared with Navy exposure field limits. Measured field levels were found to be much lower than the levels established by the Navy exposure field limits.

REFERENCES

1. "Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices," SAE J551, Society of Automotive Engineers, March 1990.

2. "Military Standard, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference," Military Standard MIL-STD-461C4, August 1986.

3. O. Zelaya, "Unit Test Procedure (UTPR) for Open-Field Measurement of Electromagnetic Interference (EMI) for the ARPA Electric and Hybrid Electric Vehicle Program," NUWC-NPT Technical Memorandum 961037, Naval Undersea Warfare Center Division, Newport, RI, 3 May 1996.

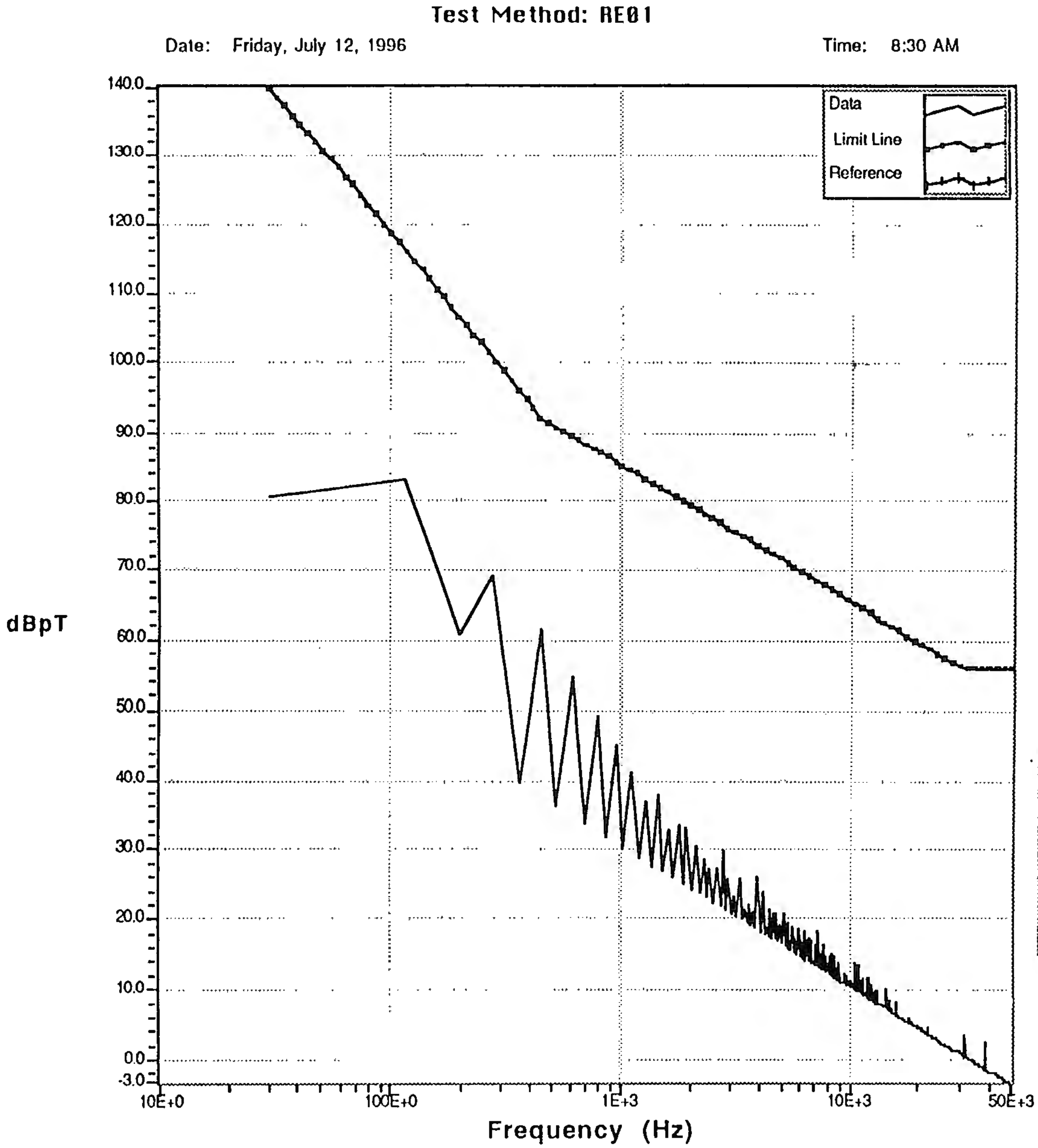
4. D. Brown, "Electricmagnetic Emission Testing Performed on Two Electric-Powered Vehicles and One Gasoline-Powered Vehicle," Test Report No. DTB01R95-0811, 24 October 1995.

5. D. Dixon et al., "Summary of EMI Test Results for the ARPA Electric Vehicle Technology Program," NUWC-NPT Technical Memorandum 941141, Naval Undersea Warfare Center Division, Newport, RI 5 November 1994.

6. Naval Operations Instruction (OPNAVINST 5100.23D), Chief of Naval Operations, Washington, DC.

APPENDIX

TEST DATA PLOTS



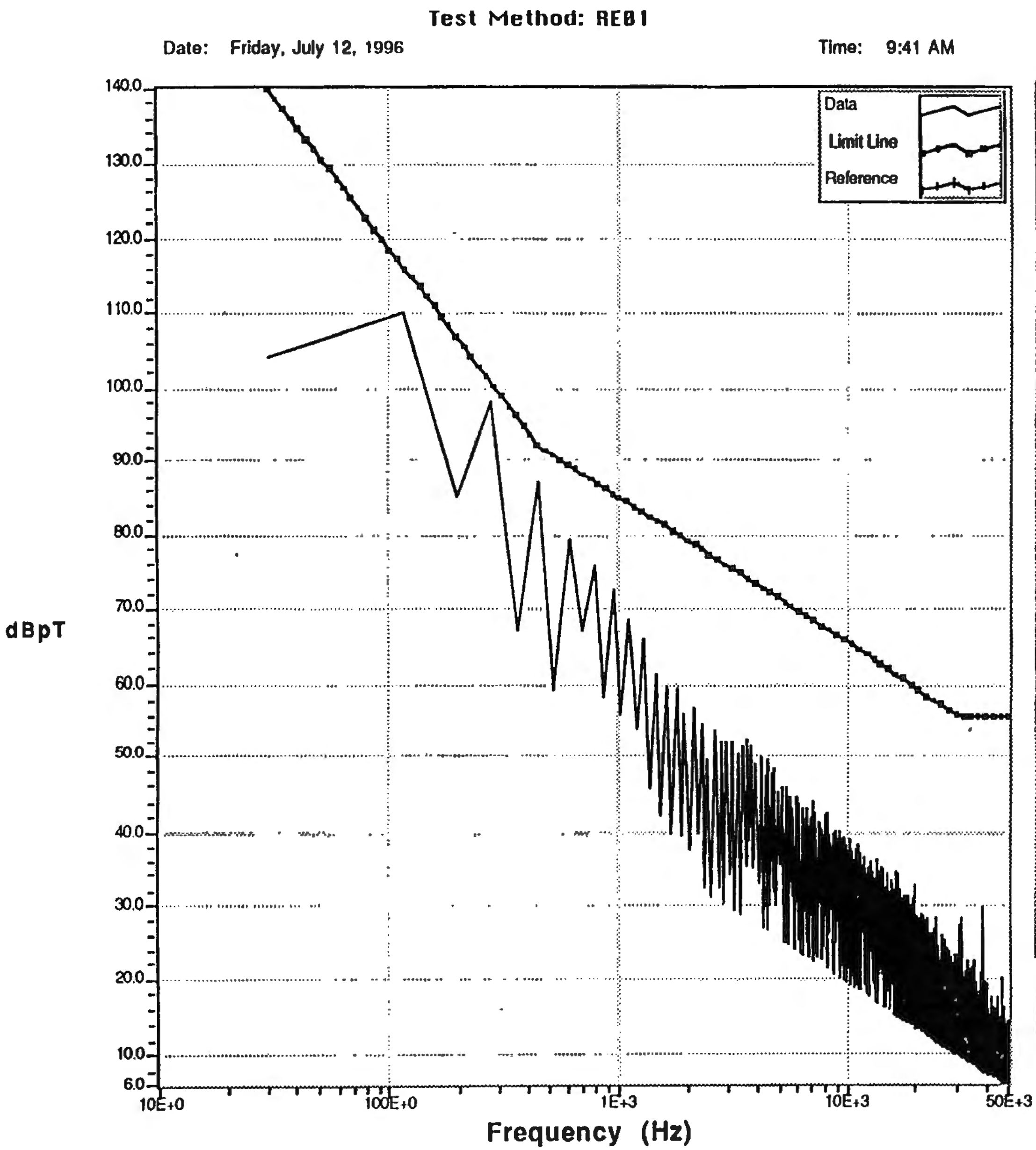
Test Info Table

8/3/95	11:12 AM
Car	CMEEC Truck
Test site	Fishers Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	EMCO 5 1/2" Loop SN 2163
Amplifier:	HP8447F (26db)
BandWidth:	1 0

Remarks

Magnetic Field Measurements taken at Ambient Condition

Figure A-1. CMEEC Vehicle in Open Field, B Field Measurements Taken at Ambient Condition



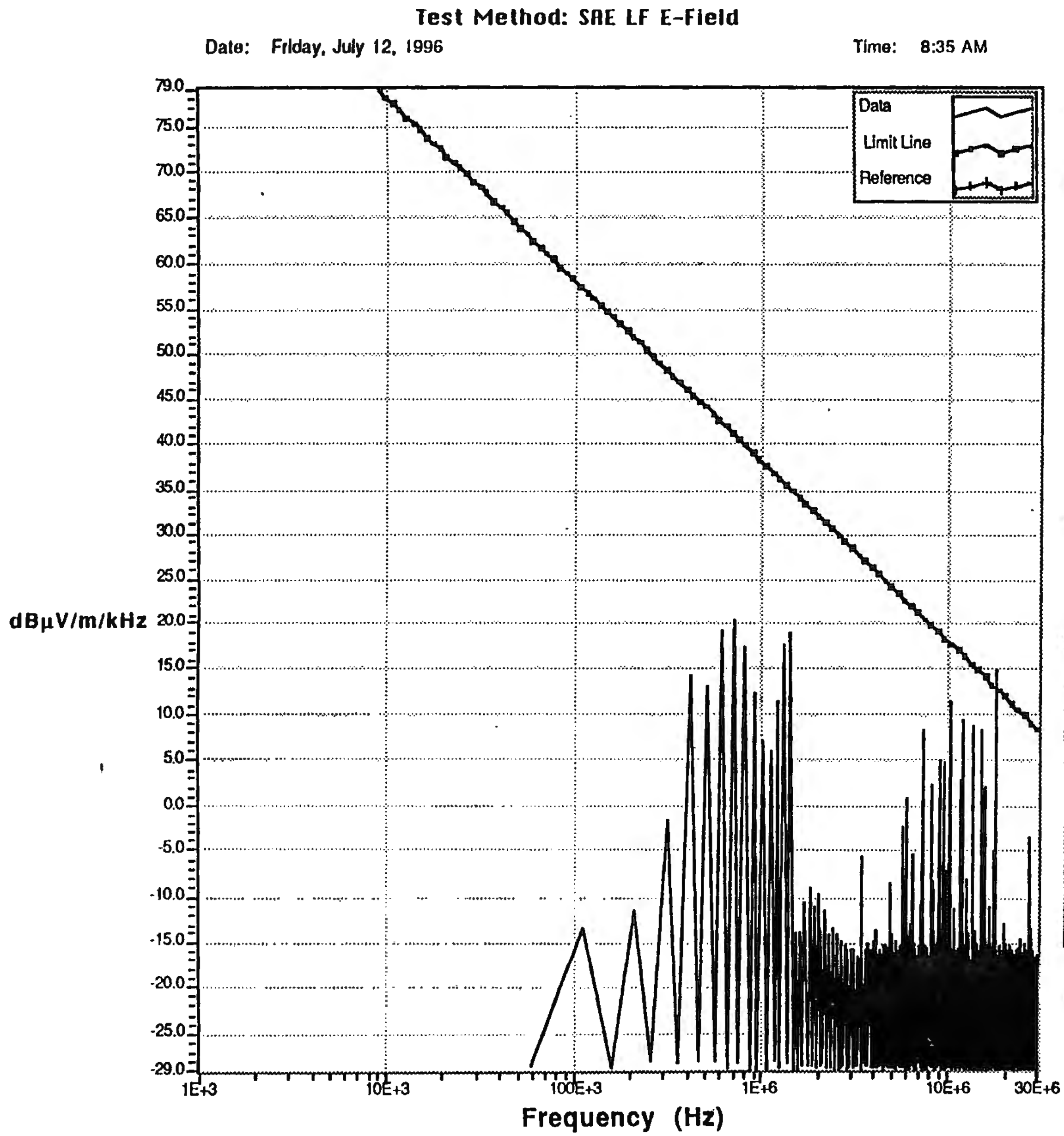
Test Info Table

8/3/95	2:16 PM
Car	CMEEC Truck
Test site	Fishers Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	EMCO 5 1/2" Loop SN 2163
Amplifier:	None
BandWidth:	10

Remarks

Magnetic Field Measurements taken at 35 mph in 5th gear condition with car jacked up and antenna located at 1 m from the Front side section of the car

Figure A-2. CMEEC Vehicle in Open Field, B Field Measurements Taken 1 m from the Front Side



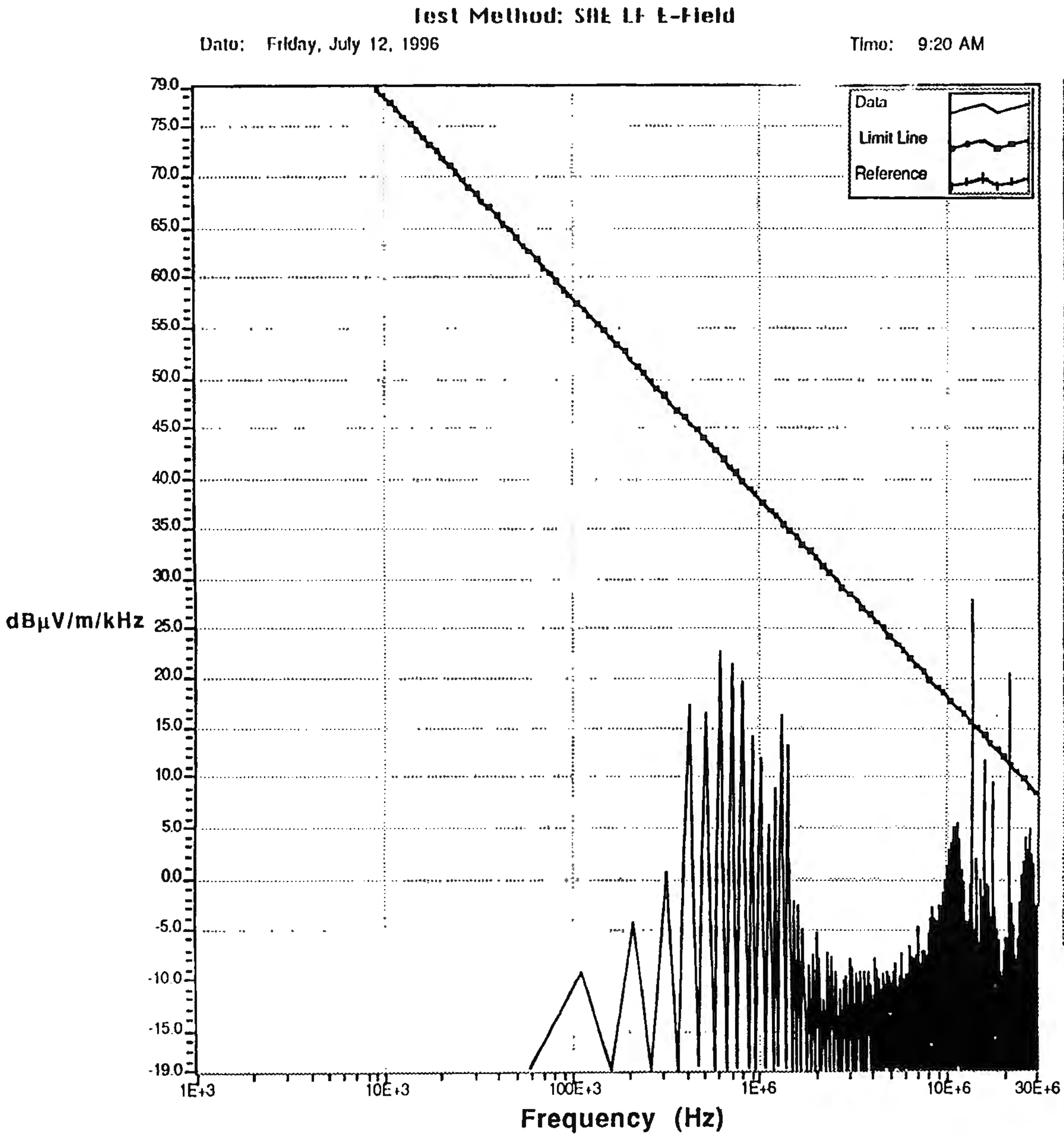
Test Info Table

8/3/95	9:58 AM
Car	CMEEC Truck
Test site	Fishers Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	No Current Probe
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurements taken at Ambient Condition

Figure A-3. CMEEC Vehicle in Open Field, E Field (0.009-30 MHz) Taken at Ambient Condition



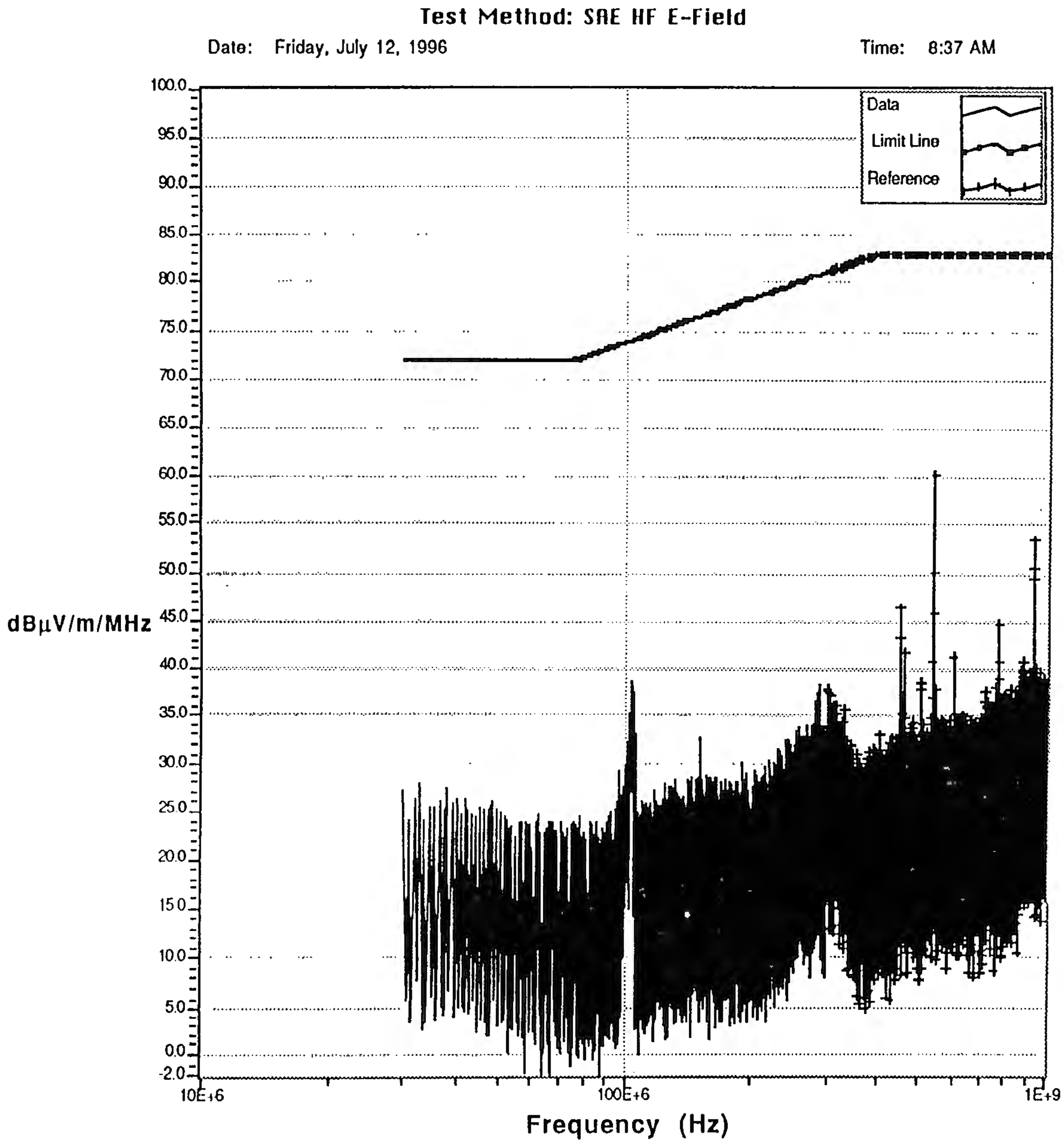
Test Info Table

8/3/95	2:03 PM
Car	CMEEC Truck
Test site	Fishers Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	BB Active MP SAS-200/550
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurements taken at 35 mph in 5th gear condition with car jacked up and antenna located at 1 m from the Front side section of the car

Figure A-4. CMEEC Vehicle in Open Field, E Field (0.009-30 MHz) Taken 1 m from the Front Side



Test Info Table

8/3/95	10:12 AM
Car	CMEEC Truck
Test site	Fishers Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	1000000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	1000000

Remarks

Electric Field Measurements taken at Ambient Condition with antenna phasing Horizontal Polarization

Figure A-5. CMEEC Vehicle in Open Field, E Field (30-1000 MHz) Taken at Ambient Condition

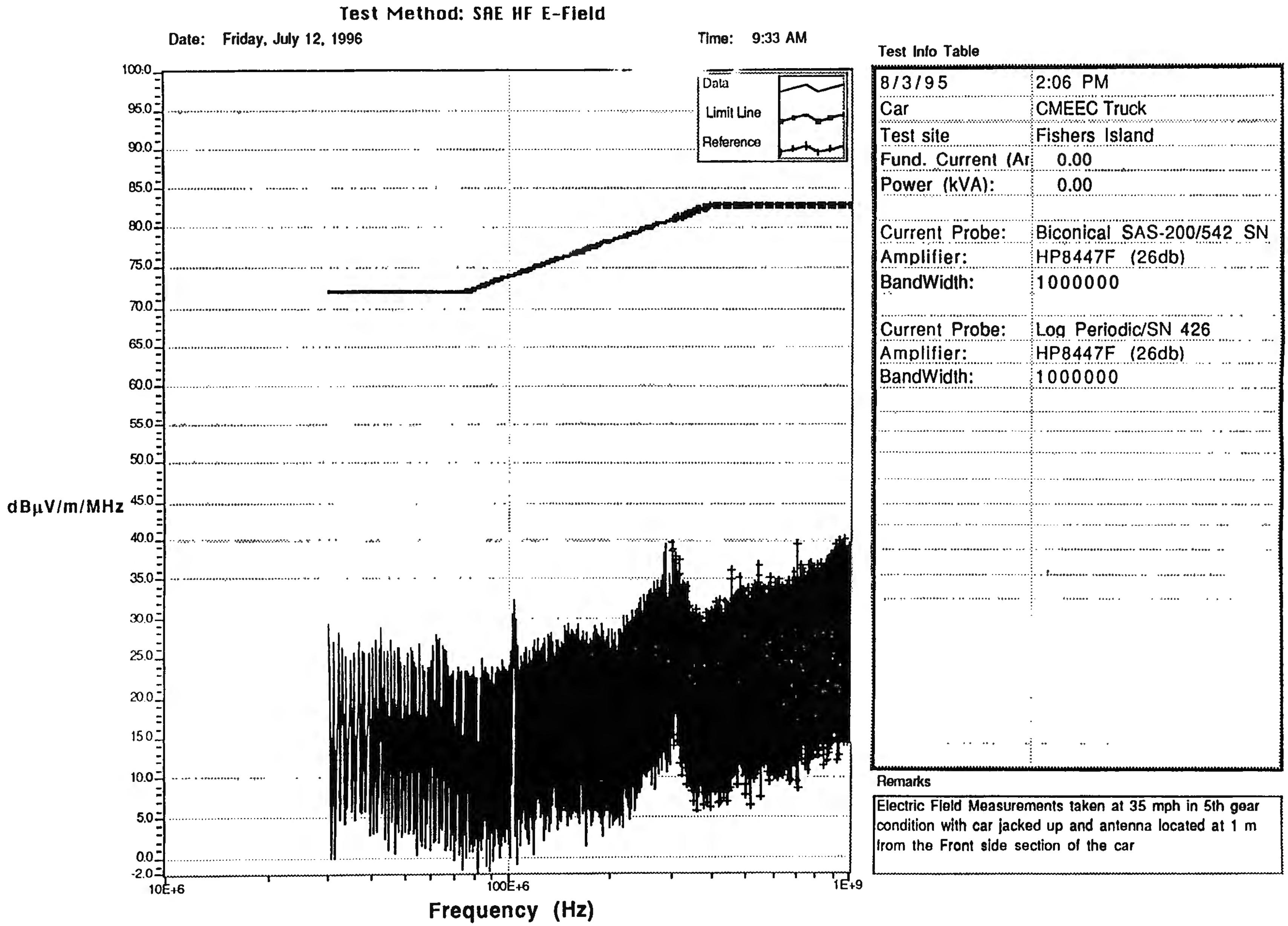


Figure A-6. CMEEC Vehicle in Open Field, E Field (30-1000 MHz) Taken 1 m from the Front Side

Dayton T. Brown Inc.

MIL-STD-461C RE01 CLASS A3

Date :	09/18/95	Time :	20:20:04.31	Detector	Peak	SPECS	
Technician :	C. TREADWELL	Job Number	: 409175-00-000	Bandwidth	Per Table	1) MIL-STD-461C RE01	
Customer:	McLaughlin Research	Test Number	: 9175015	Impedence	50 Ohm	2)	
Test Item :	CMEEC	Sensor Loc.	: Driver Side	RF Atten.	60 dB	3)	
Mode of Op. :	AMBIENT	Sensor Pol.	:	High Pass	16 Hz	4)	
Serial No. :	291-GRO	Ext. Atten.	: 0 dB	Low Pass	50 kHz		
				Output	IF		

EMC-11 SETTINGS

Comment :

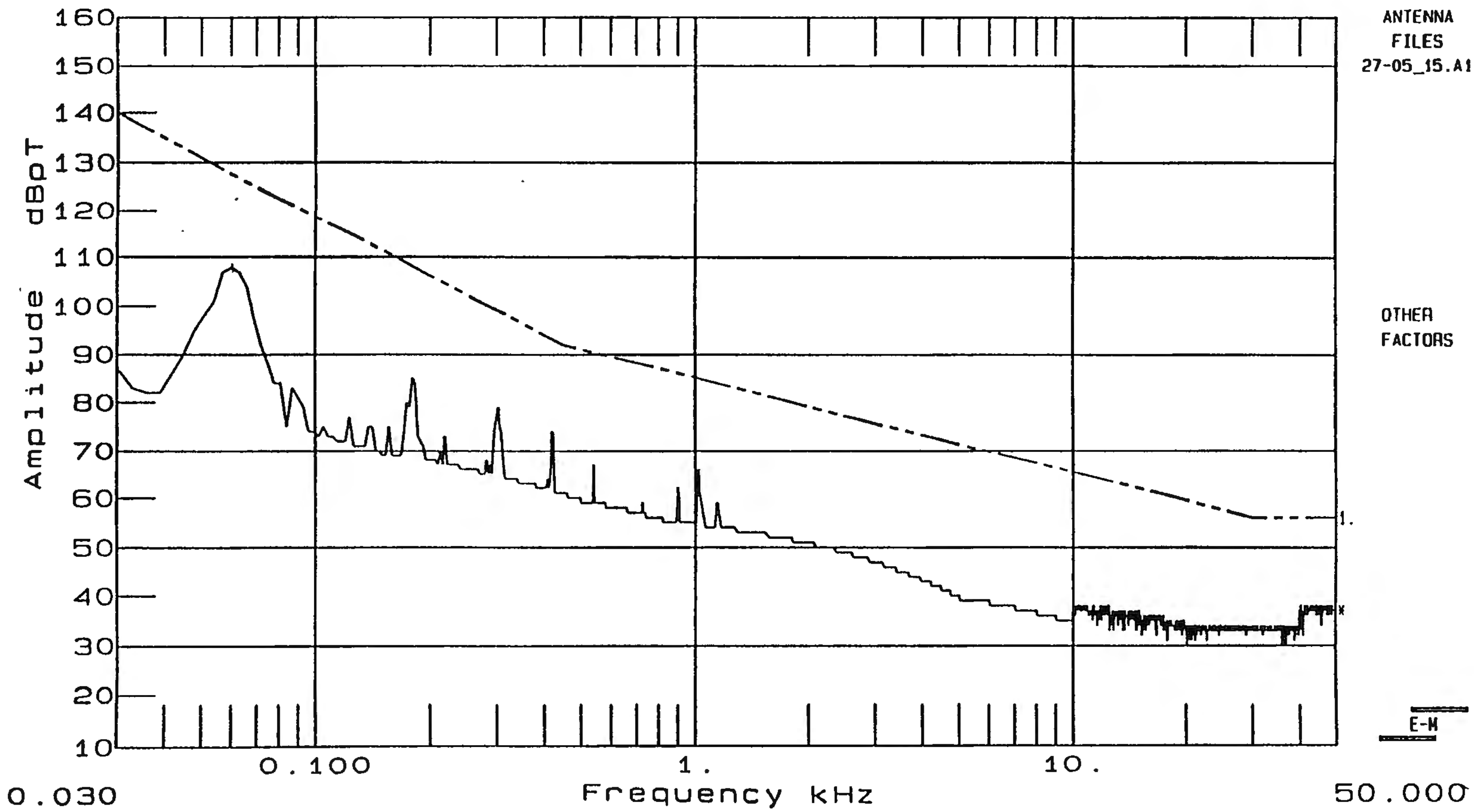


Figure A-7. CMEEC Vehicle in Anechoic Room, B Field Measurements Taken at Ambient Condition

Dayton T. Brown Inc.

MIL-STD-461C RE01 CLASS A3

Date :	09/18/95	Time :	15: 25: 40.71	EMC-11 SETTINGS		SPECS
Technician :	V.MIrkov V.M.	Job Number	: 409175-00-000	Detector	Peak	1) MIL-STD-461C RE01
Customer:	McLaughlin Research	Test Number	: 9175003	Bandwidth	Per Table	2)
Test Item :	CMEEC	Sensor Loc.	: Driver Side	Impedence	50 Ohm	3)
Mode of Op. :	Drive	Sensor Pol.	:	RF Atten.	60 dB	4)
Serial No. :	291-GRO	Ext. Atten.	: 0 dB	High Pass	16 Hz	DATA FILE : 9175003.D11
				Low Pass	50 kHz	
				Output	IF	R. Vartielle

Comment : Speed at 25MPH & 25 Amps

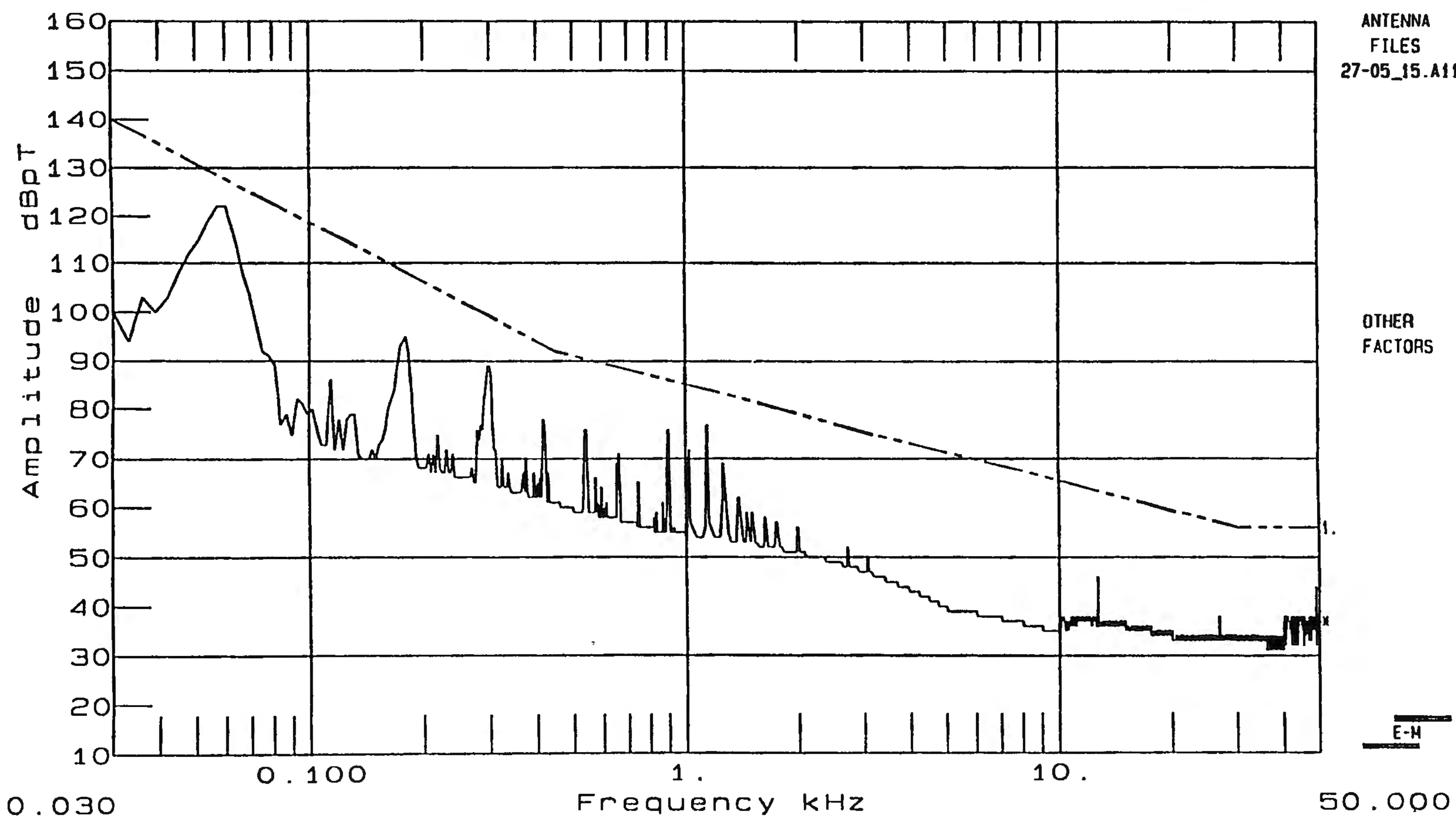


Figure A-8. CMEEC Vehicle in Anechoic Room, B Field Measurements Taken at the Driver's Side

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/19/95	Time :	11:18:25.06	EMC-30 SETTINGS		SPECS
Technician :	V.Mirkov V.M	Test Equip. :	409175-00-000	Detector	Peak	1) J551 @ 1 Meter .014-30 MHz
Test Method :	McLaughlin Research	Test Number :	9175020	Bandwidth	Per Band	2)
Equipment :	CMEEC	Sensor Loc. :	Front 1 Meter	Dwell	10 msec.	
Mode of Op. :	Ambient	Sensor Pol. :	VERTICAL	RF Atten.	0 dB	
Serial No. :	291-GRO	Ext. Atten. :	0 dB	IF Atten.	0 dB	

Comment :

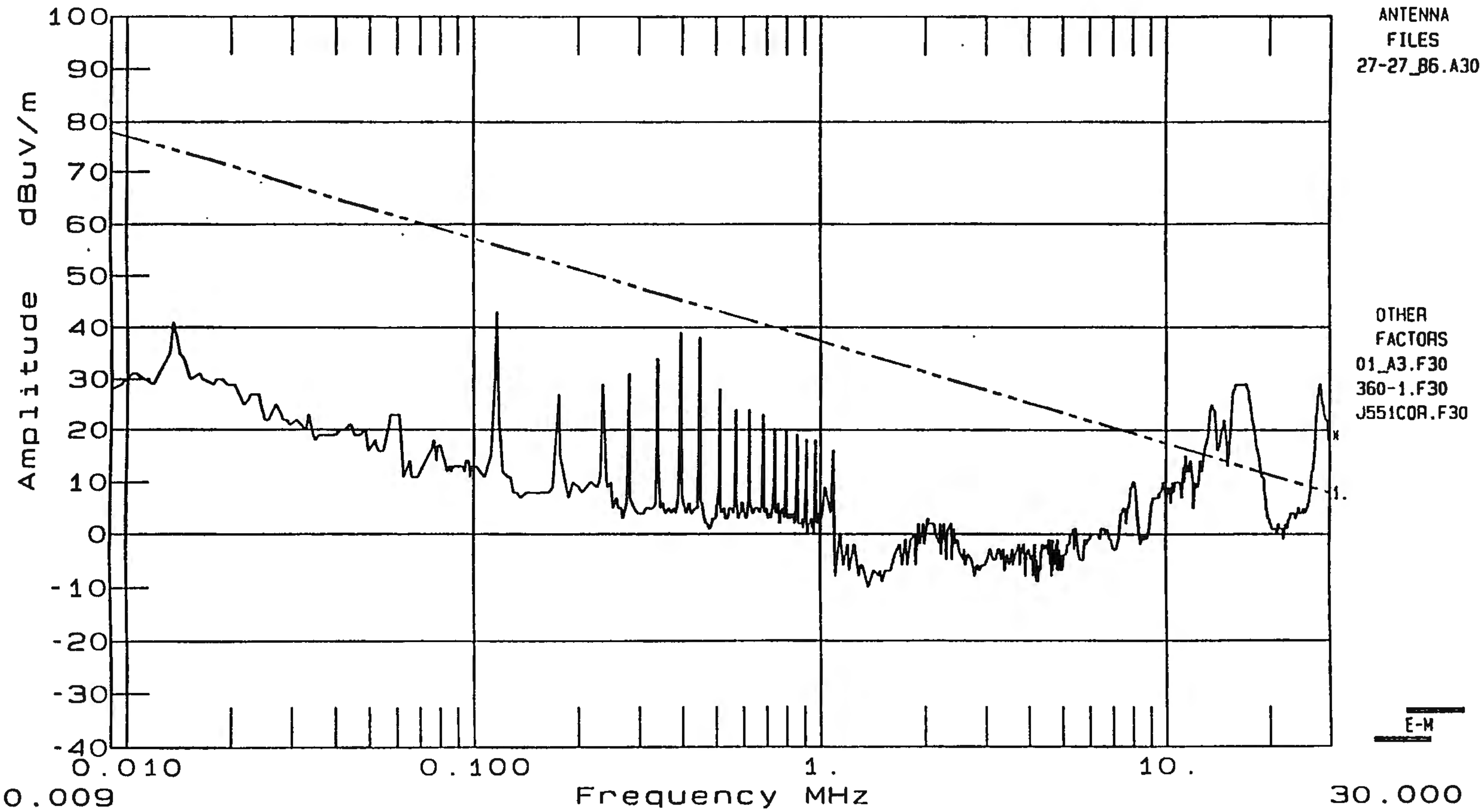


Figure A-9. CMEEC Vehicle in Anechoic Room, E Field (0.009-30 MHz) Taken at Ambient Condition

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/19/95	Time :	10: 45: 16.43	EMC-30 SETTINGS		SPECS
Technician :	V.Mirkov V.M.	Test Equip. :	409175-00-000	Detector	Peak	1) J551 @ 1 Meter .014-30 MHz
Test Method :	McLaughlin Research	Test Number :	9175019	Bandwidth	Per Band	2)
Equipment :	CMEEC	Sensor Loc. :	Front 1 Meter	Dwell	10 msec.	
Mode of Op. :	Drive	Sensor Pol. :	VERTICAL	RF Atten.	0 dB	
Serial No. :	291-GRO	Ext. Atten. :	0 dB	IF Atten.	0 dB	

Comment : Unloaded

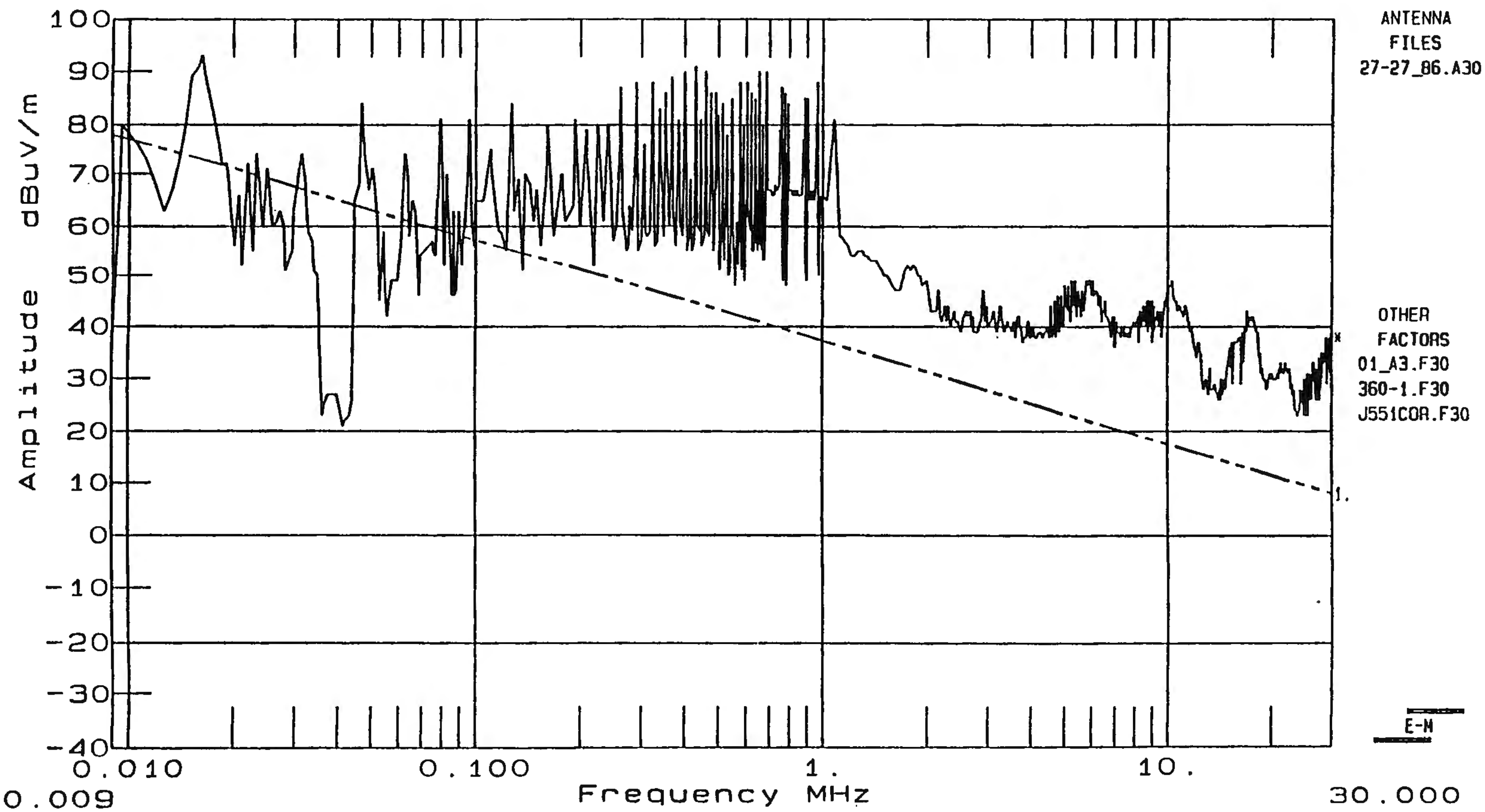


Figure A-10. CMEEC Vehicle in Anechoic Room, E Field (0.009-30 MHz) Taken 1 m from the Front Side

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/18/95	Time :	18:35:39.01	EMC-30 SETTINGS		SPECS	
Technician :	C. Treadwell	Test Equip. :	409175-00-000	Detector	Peak	1) J551 @ 1 Meter	
Test Method :	Drive	Test Number :	9175013	Bandwidth	Per Band	2)	
Equipment :	CMEEC	Sensor Loc. :	1 METER IN FRONT	Dwell	20 msec.		
Mode of Op. :	AMBIENT	Sensor Pol. :	HORIZONTAL	RF Atten.	0 dB		
Serial No. :	291-GRO	Ext. Atten. :	0 dB	IF Atten.	0 dB		

Comment :

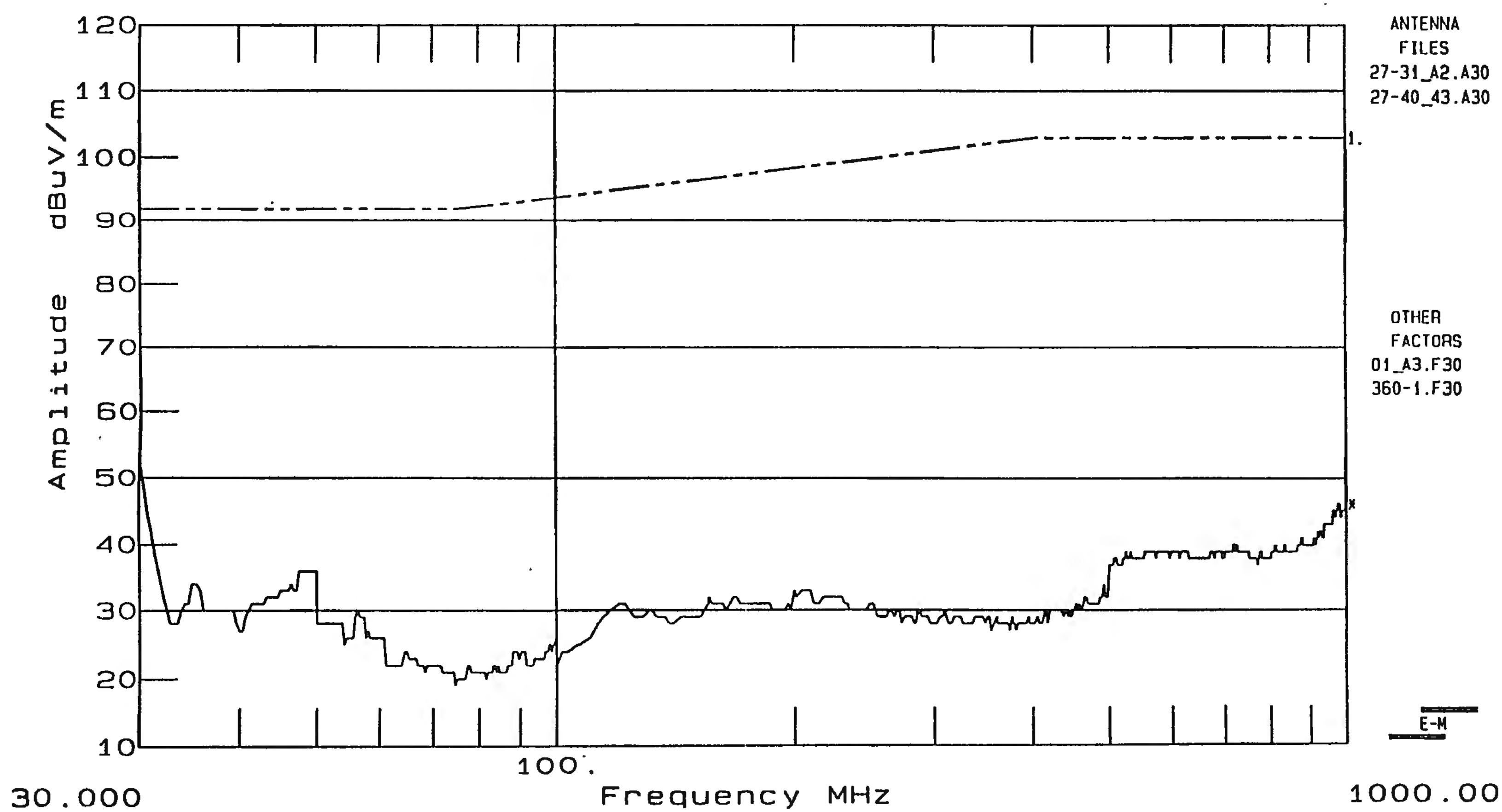


Figure A-11. CMEEC Vehicle in Anechoic Room, E Field (30-1000 MHz) Taken at Ambient Condition

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/18/95	Time :	17:08:07.81	EMC-30 SETTINGS		SPECS	
Technician :	C. Treadwell	Test Equip. :	409175-00-000	Detector	Peak	1) J551 @ 1 Meter	
Test Method :		Test Number :	9175006	Bandwidth	Per Band	2)	
Equipment :	CMEEC	Sensor Loc. :	1 METER IN FRONT	Dwell	20 msec.		
Mode of Op. :	Drive	Sensor Pol. :	HORIZONTAL	RF Atten.	0 dB		
Serial No. :	291-GRO	Ext. Atten. :	0 dB	IF Atten.	0 dB		

Comment : TEST ITEM NOT UNDER LOAD. 2.5 MPH, 25A

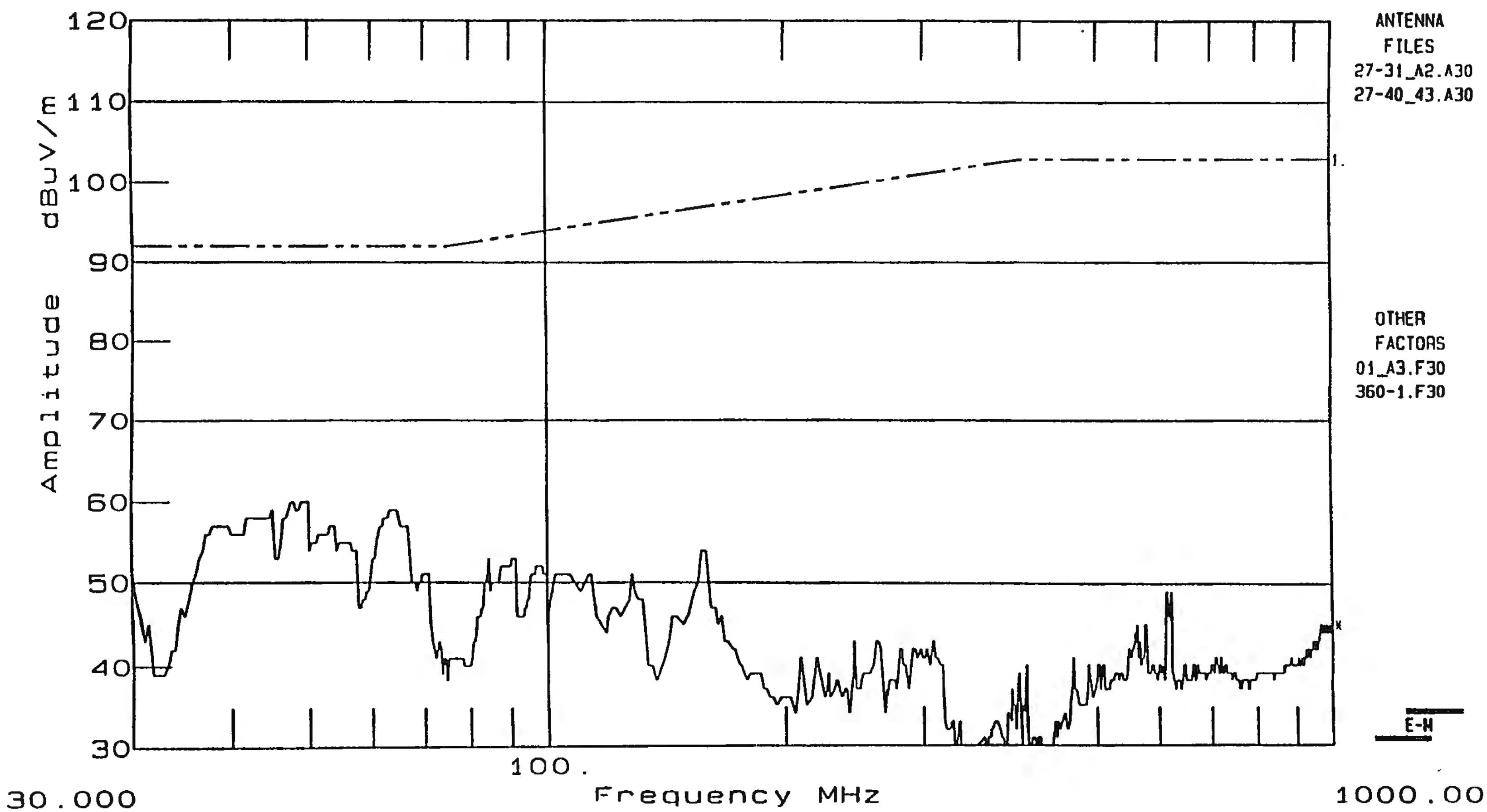
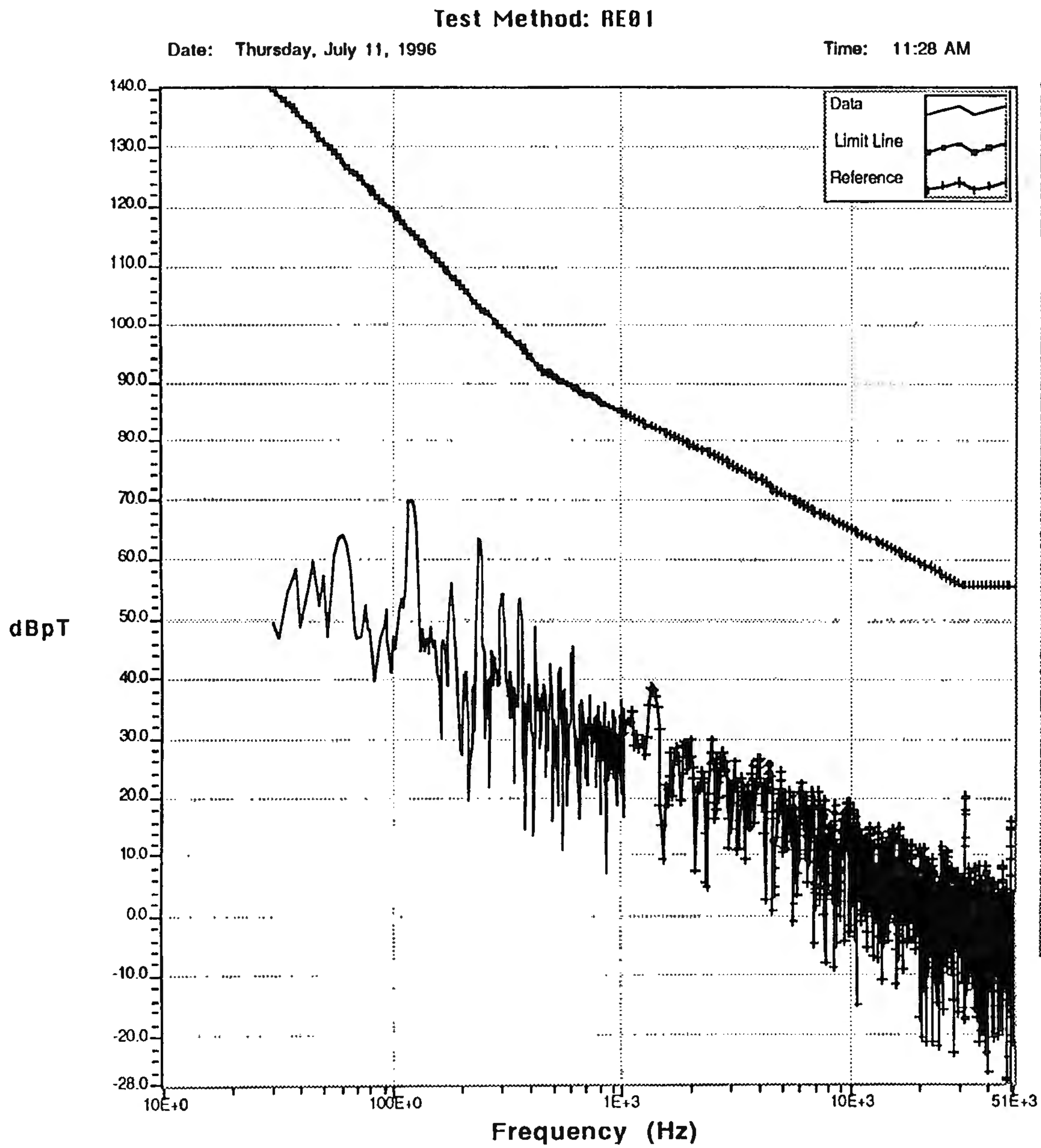


Figure A-12. CMEEC Vehicle in Anechoic Room, E Field (30-1000 MHz) Taken 1 m from the Front Side



Test Info Table

8/9/95	4:20 PM
Car	Kaman Bus
Test site	"Hudson, MA"
Fund. Current (Ar	0
Power (kVA):	0
Current Probe:	"EMCO 5 1/2"" Loop SN 216
Amplifier:	None
BandWidth:	1 0
Current Probe:	"EMCO 5 1/2"" Loop SN 216
Amplifier:	None
BandWidth:	1 0 0

Remarks

Magnetic Field Ambient Measurements taken on the Bus

Figure A-13. Hybrid Electric Bus in Open Field, B Field Measurements Taken at Ambient Condition

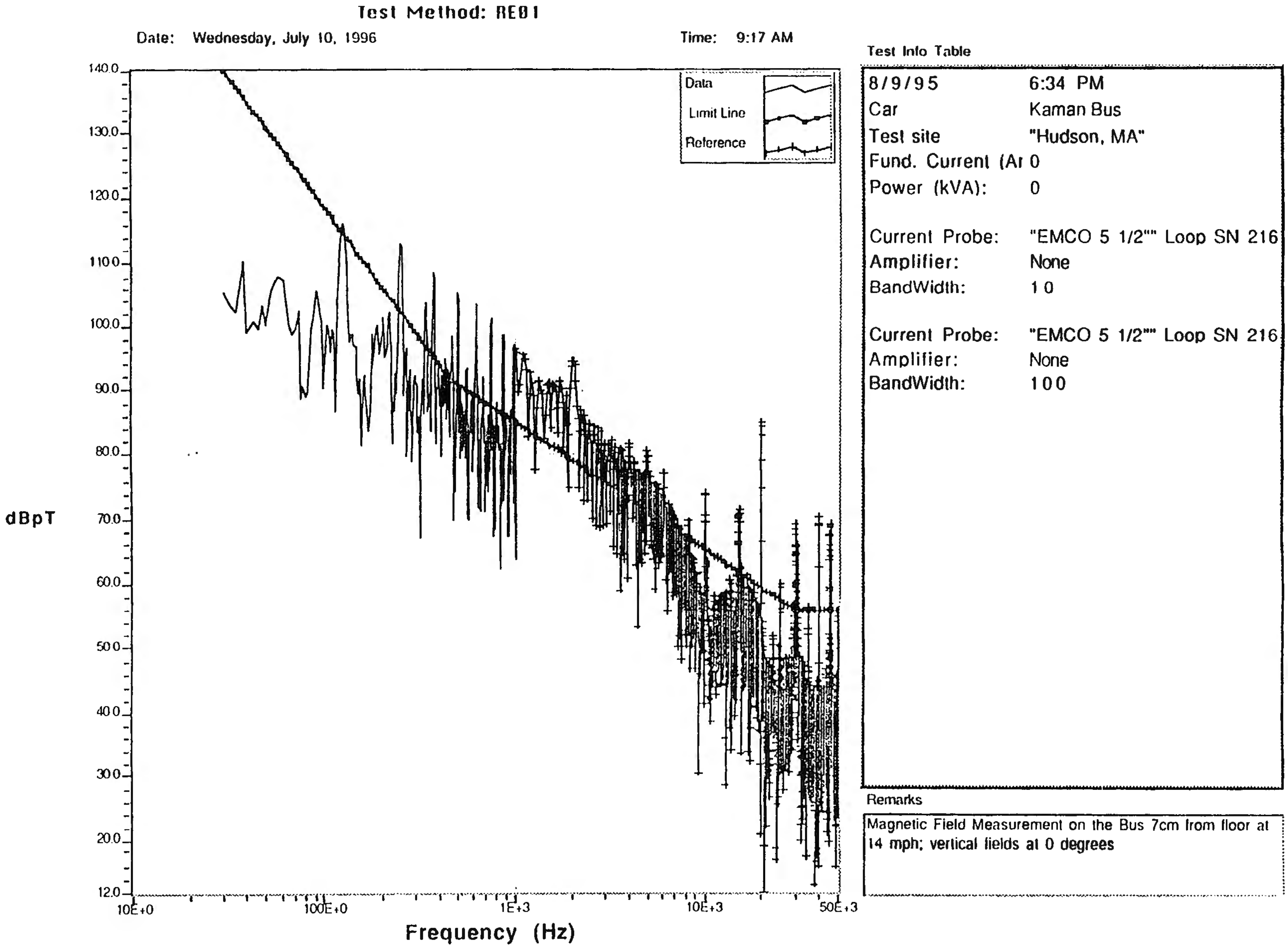
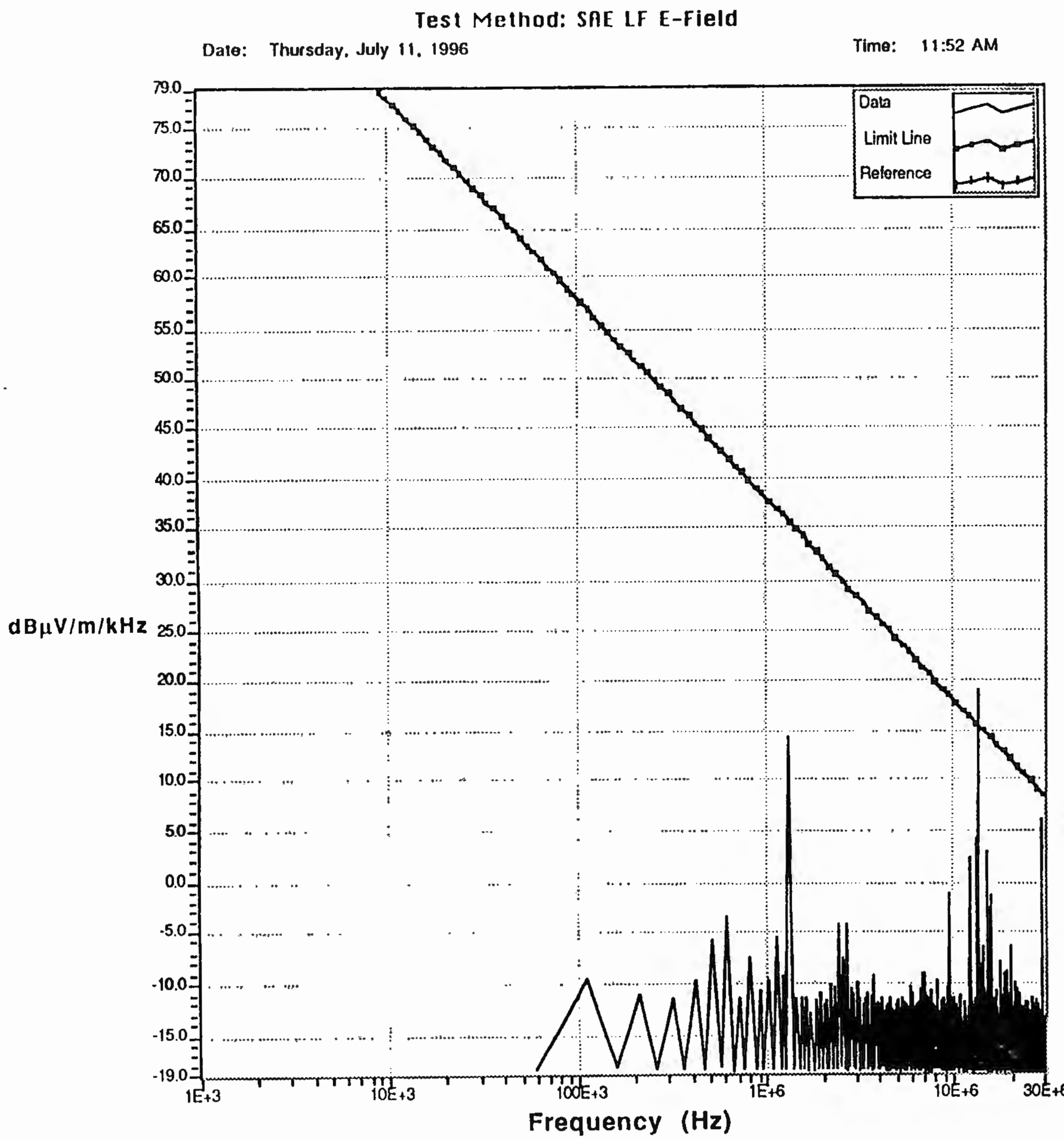


Figure A-14. Hybrid Electric Bus in Open Field, B Field Measurements Taken 7 cm from the Floor



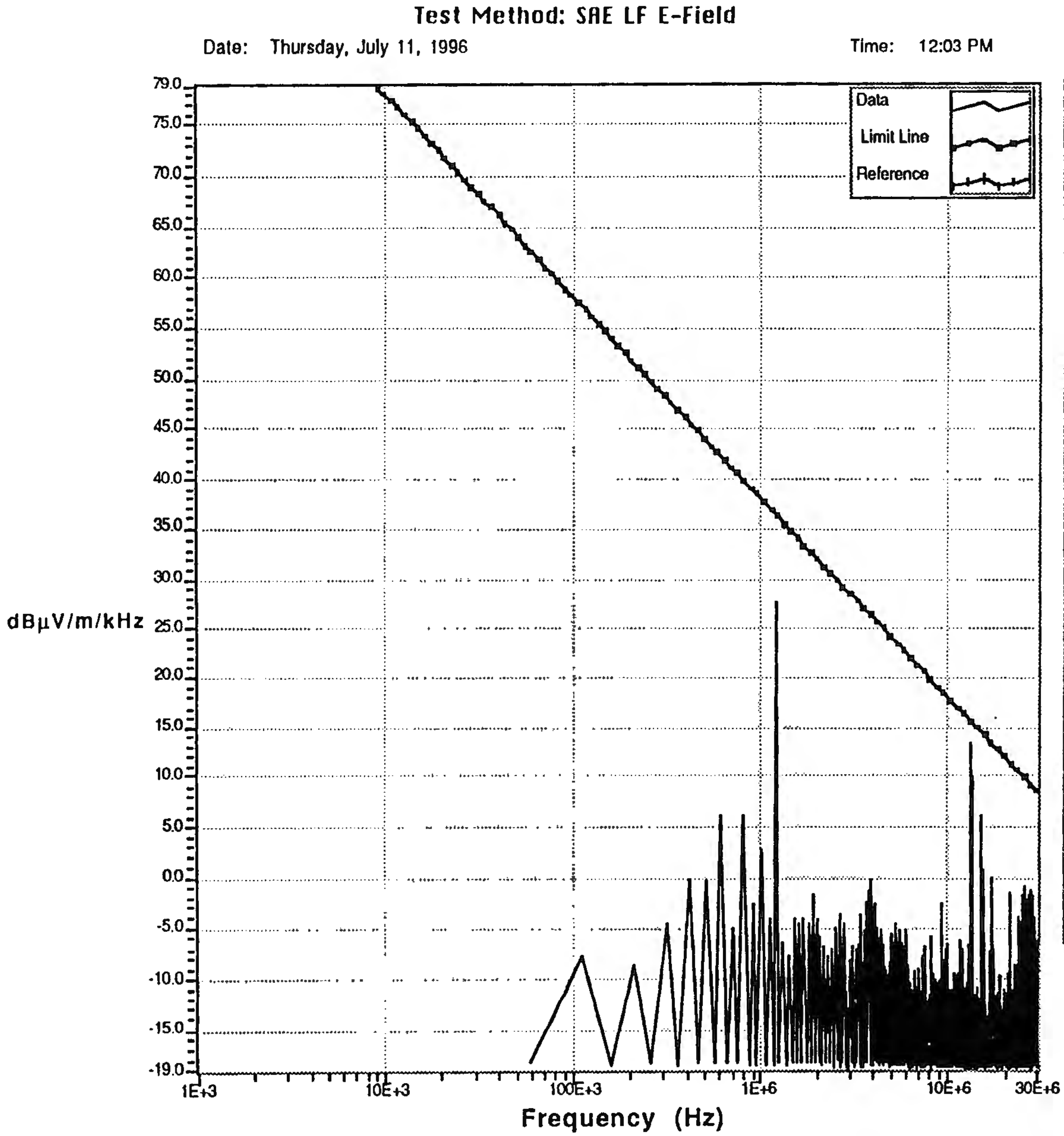
Test Info Table

8/9/95	2:08 PM
Car	Kaman Bus
Test site	Hudson, MA
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	BB Active MP SAS-200/550
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Ambient Measurements

Figure A-15. Hybrid Electric Bus in Open Field, E Field (0.009-30 MHz) Taken at Ambient Condition



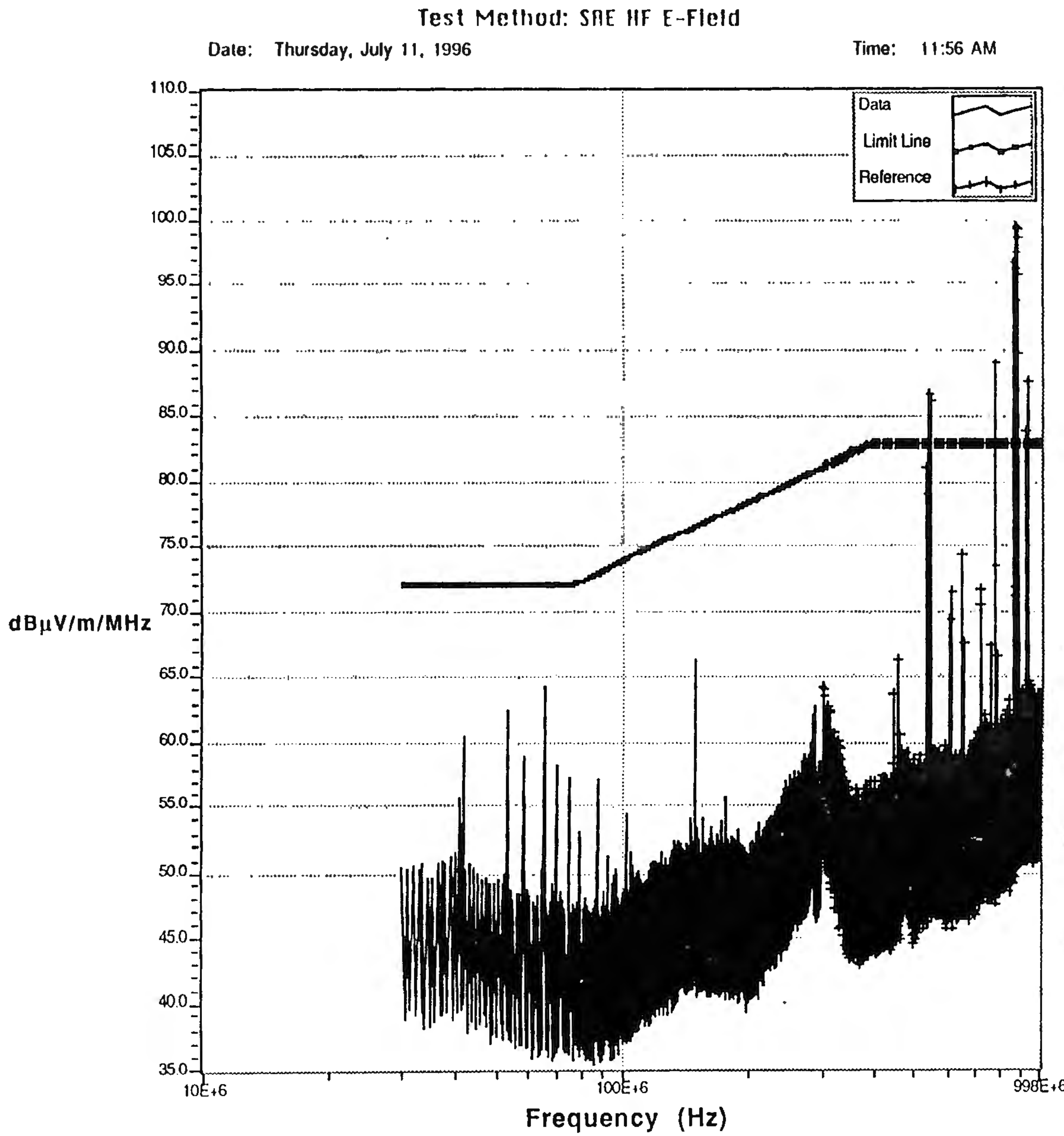
Test Info Table

8/17/95	2:11 PM
Car	Kaman Bus
Test site	Hudson, MA
	parking lot
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	BB Active MP SAS-200/550
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurements taken at 1m from behind the bus at Idle condition with antenna phasing Vertical Polarization

Figure A-16. Hybrid Electric Bus in Open Field, E Field (0.009-30 MHz) Taken 1 m Behind in Idle Condition



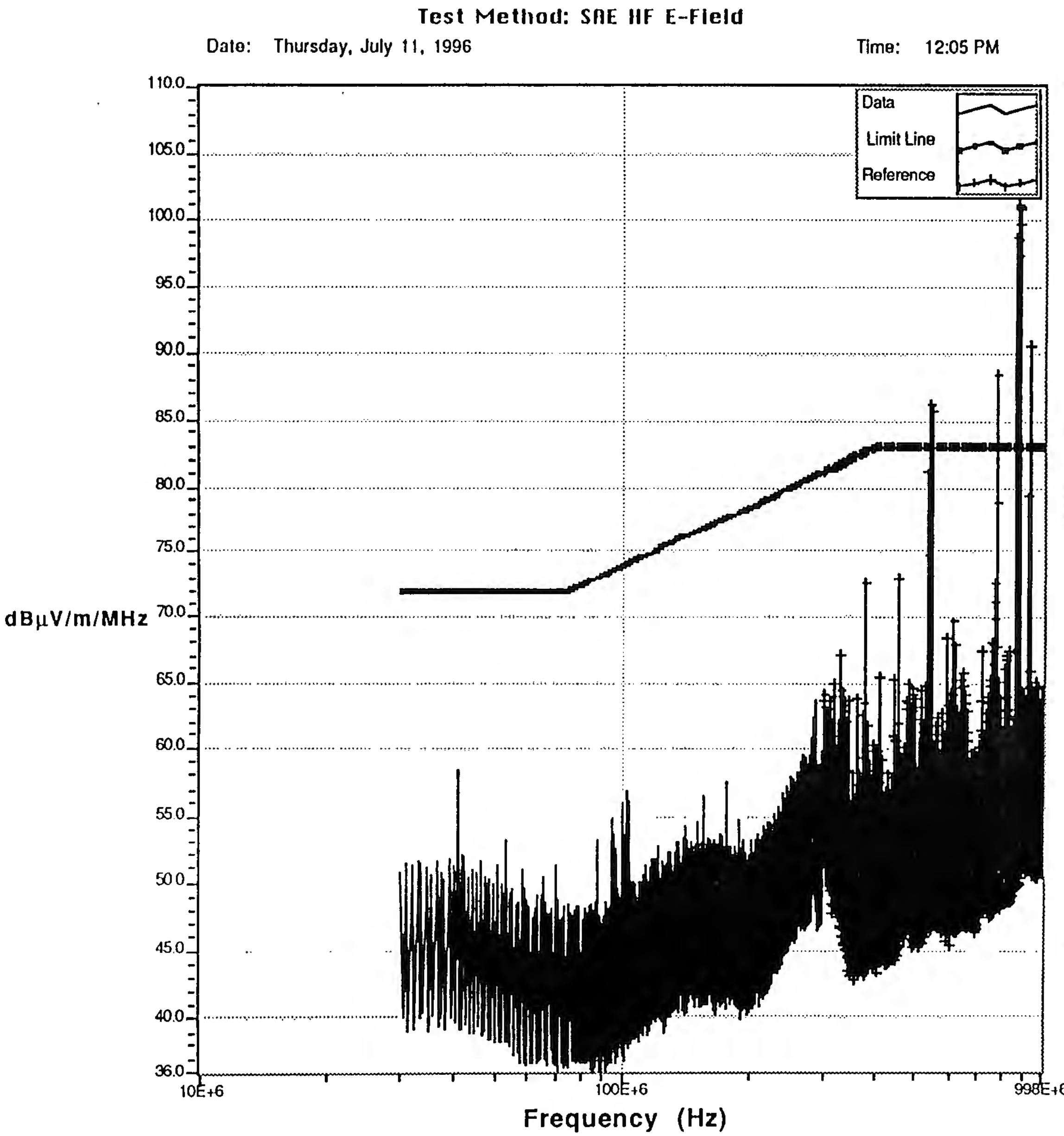
Test Info Table

8/17/95	2:00 PM
Car	Kaman Bus
Test site	Hudson, MA
	parking lot
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	10000
Current Probe:	No Current Probe
Amplifier:	HP8447F (26db)
BandWidth:	10000

Remarks

Electric Field Measurements taken at Ambient Condition with antenna phasing Vertical Polarization

Figure A-17. Hybrid Electric Bus in Open Field, E Field (30-1000 MHz) Taken at Ambient Condition



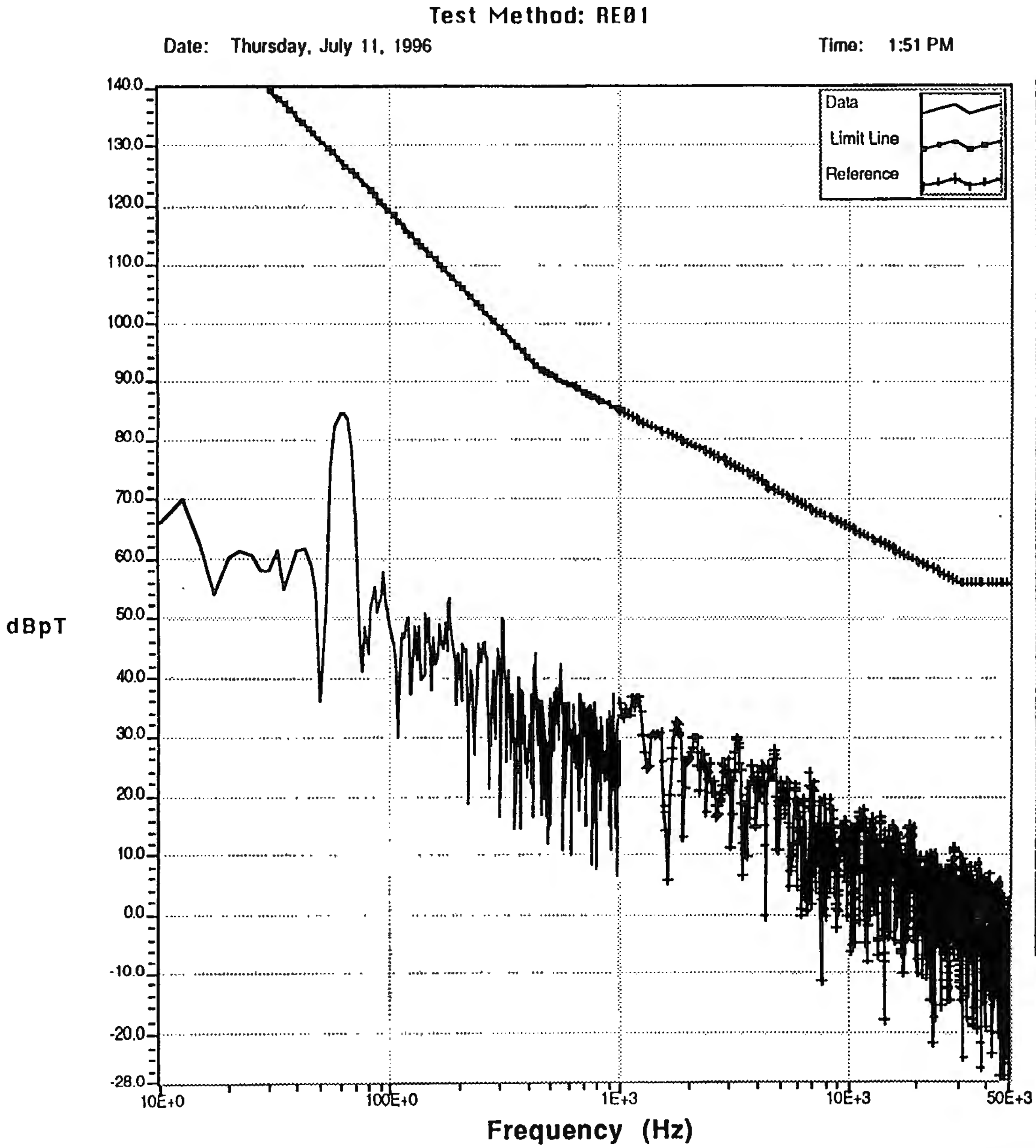
Test Info Table

8/17/95	2:14 PM
Car	Kaman Bus
Test site	Hudson, MA
	parking lot
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	10000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	10000

Remarks

Electric Field Measurements taken at 1m from behind the bus at Idle condition with antenna phasing Vertical Polarization

Figure A-18. Hybrid Electric Bus in Open Field, E Field (30-1000 MHz) Taken 1 m Behind in Idle Condition



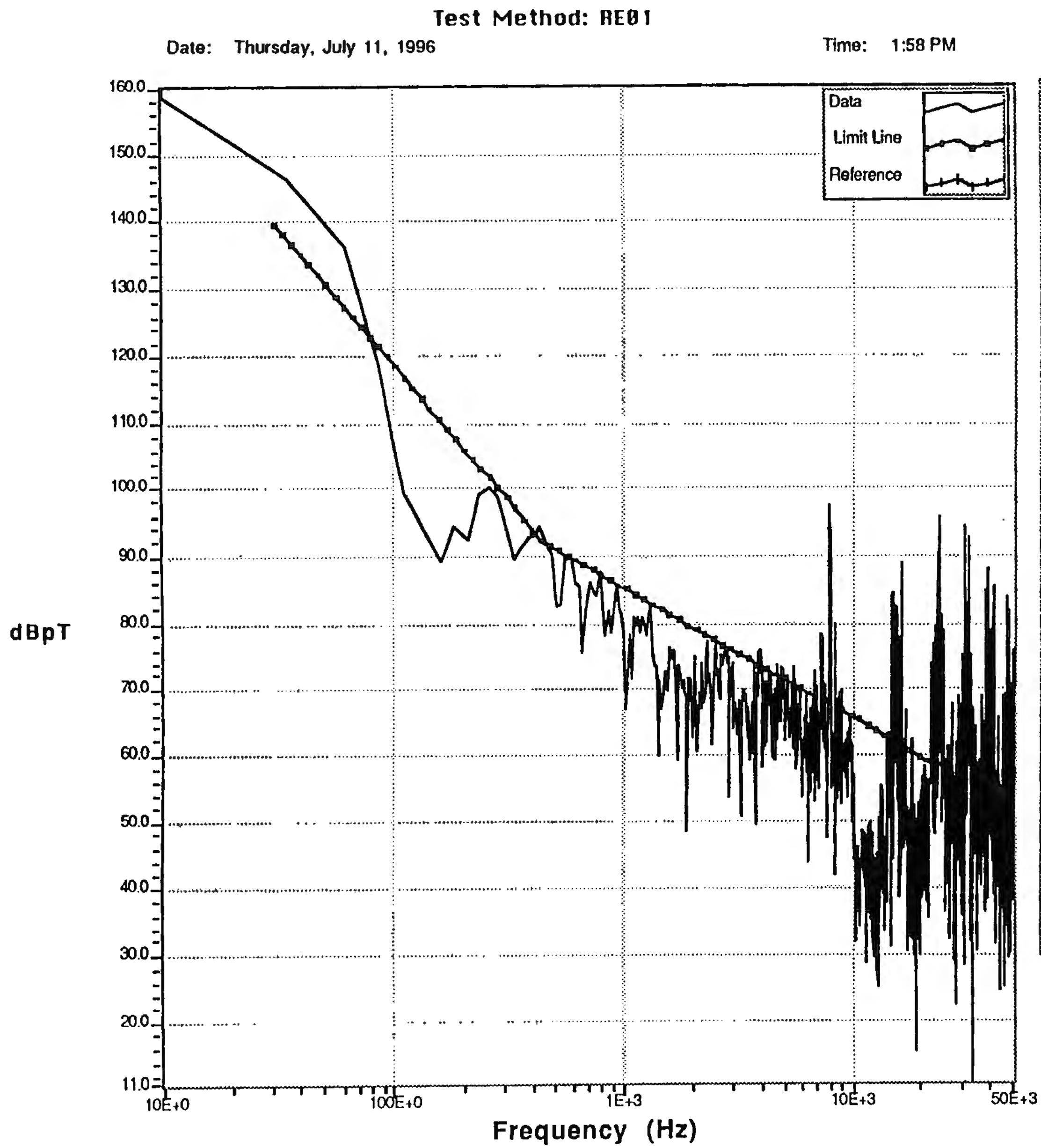
Test Info Table

8/23/95	1:32 PM
Car	Robins AFB DD2
Test site	"Robins AFB, Training Site"
Fund. Current (Ar	0
Power (kVA):	0
Current Probe:	"EMCO 5 1/2"" Loop SN 216
Amplifier:	None
BandWidth:	10
Current Probe:	"EMCO 5 1/2"" Loop SN 216
Amplifier:	None
BandWidth:	100

Remarks

Magnetic Field Ambient Measurements

Figure A-19. Dodge Dakota Vehicle in Open Field, B Field Measurements Taken at Ambient Condition



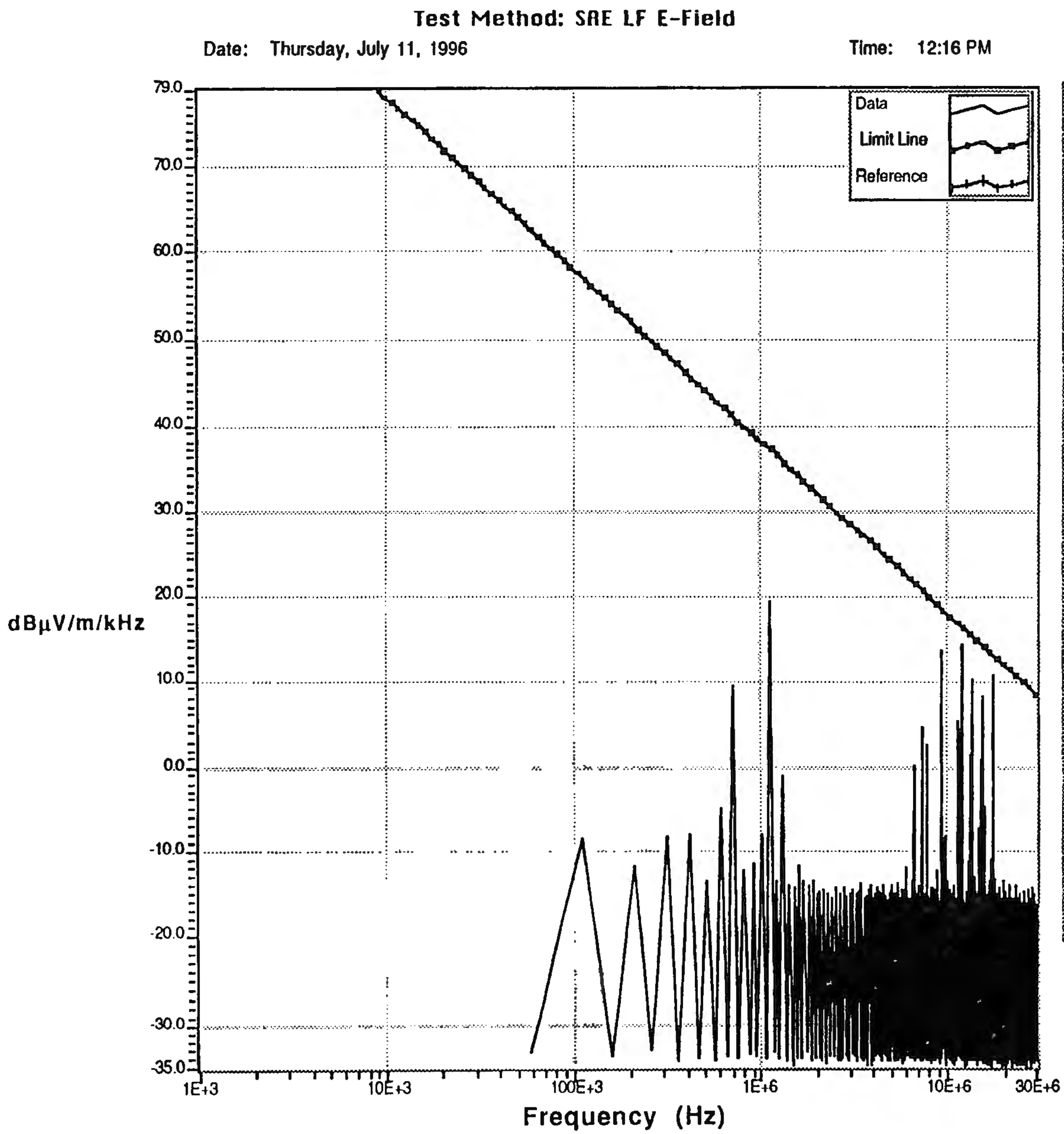
Test Info Table

8/23/95	2:18 PM
Car	Robins AFB DD2
Test site	Robins AFB, Training Site
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	EMCO 5 1/2" Loop SN 2163
Amplifier:	None
BandWidth:	100

Remarks

Magnetic Field Measurements with Loop antenna located at 7 centimeters from the passenger side of the car. Car jacked up and running 40 mph

Figure A-20. Dodge Dakota Vehicle in Open Field, B Field Measurements Taken 7 cm from the Passenger's Side



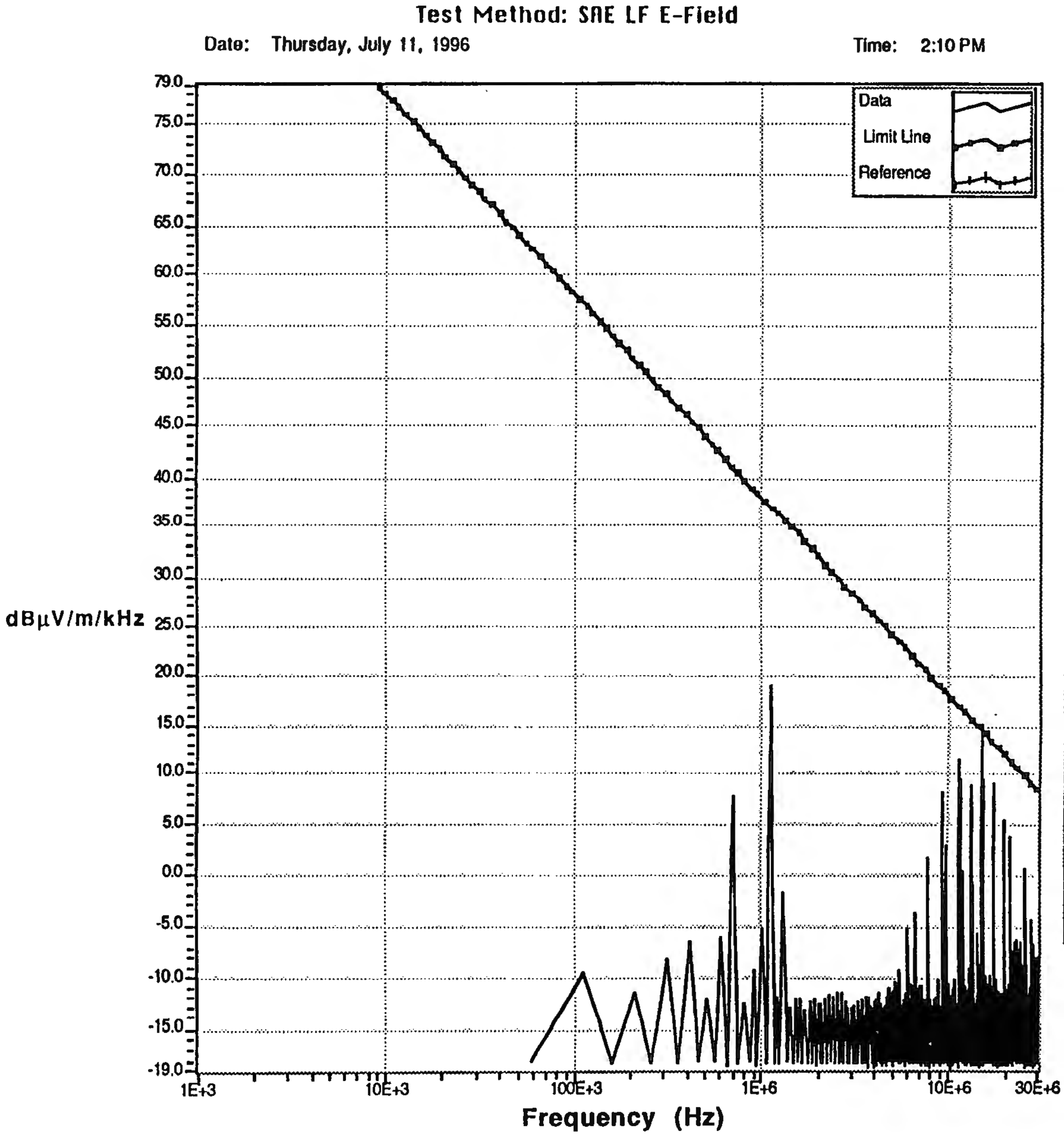
Test Info Table

8/22/95	4:14 PM
Car	Robins AFB DD2
Test site	Robins AFB, Training Site
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	No Current Probe
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurements taken at Ambient Conditon with antenna phasing Horizontal Polarization

Figure A-21. Dodge Dakota Vehicle in Open Field, E Field (0.009-30 MHz) Taken at Ambient Condition



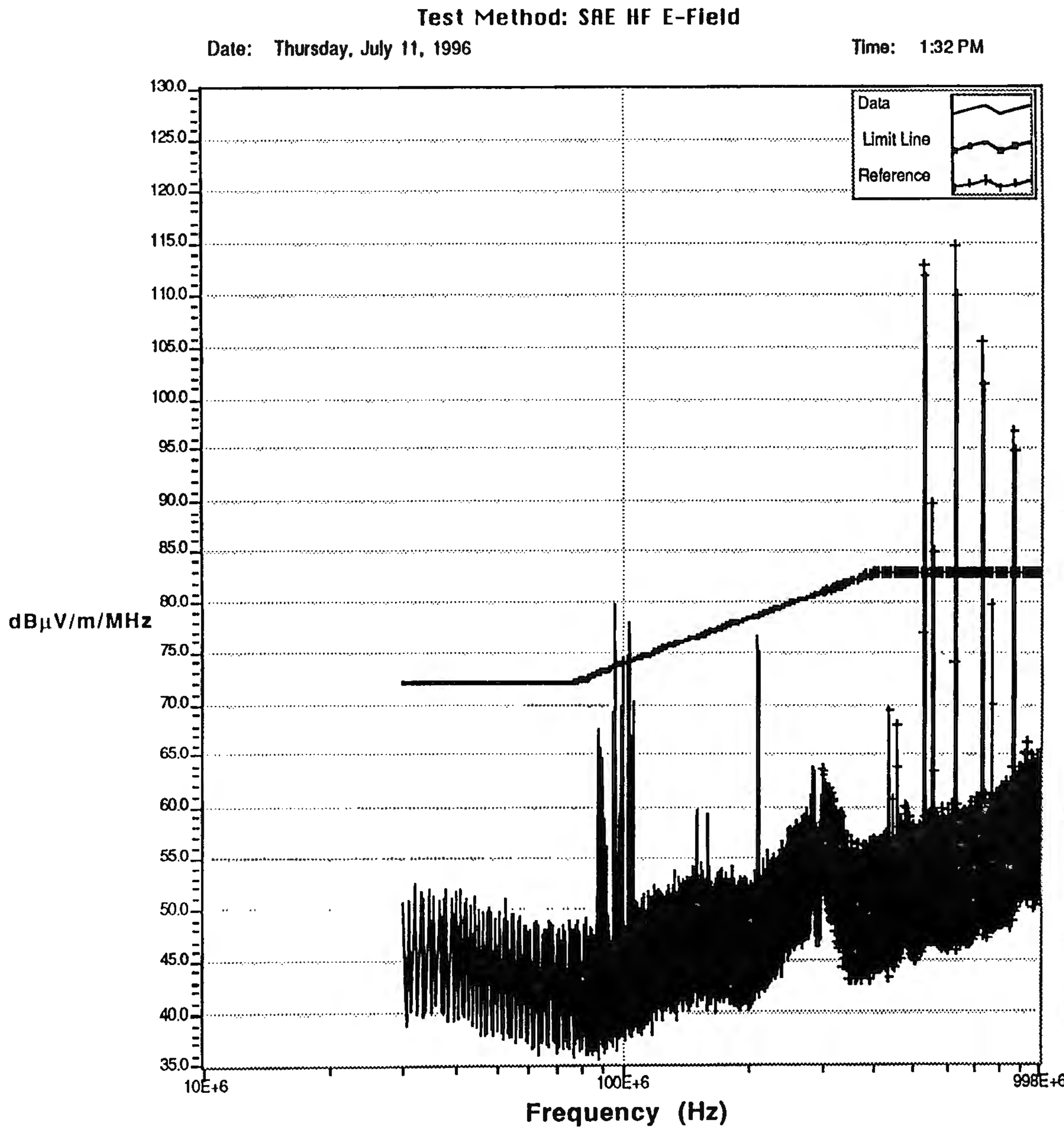
Test Info Table

8/22/95	5:02 PM
Car	Robins AFB DD2
Test site	Robins AFB, Training Site
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	BB Active MP SAS-200/550
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurements with antenna located at 1 meter from the front side of the car and 1 meter up from the ground. Car jacked up and running 30 mph

Figure A-22. Dodge Dakota Vehicle in Open Field, E Field (0.009-30 MHz) Taken 1 m from the Front Side



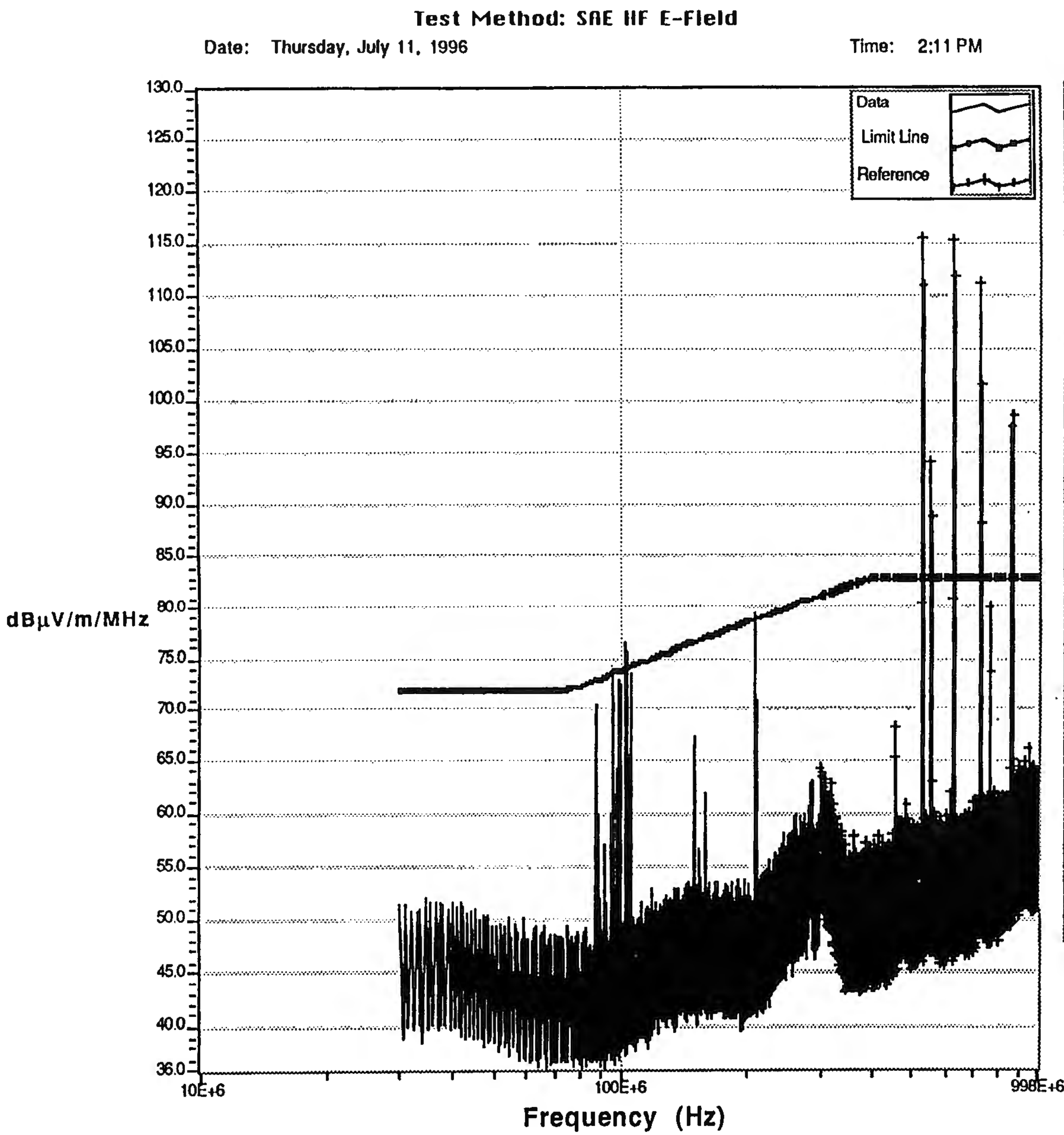
Test Info Table

8/22/95	4:25 PM
Car	Robins AFB DD2
Test site	Robins AFB, Training Site
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	10000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	10000

Remarks

Electric Field Measurements taken at Ambient Condition with antenna phasing Horizontal Polarization

Figure A-23. Dodge Dakota Vehicle in Open Field, E Field (30-1000 MHz) Taken at Ambient Condition



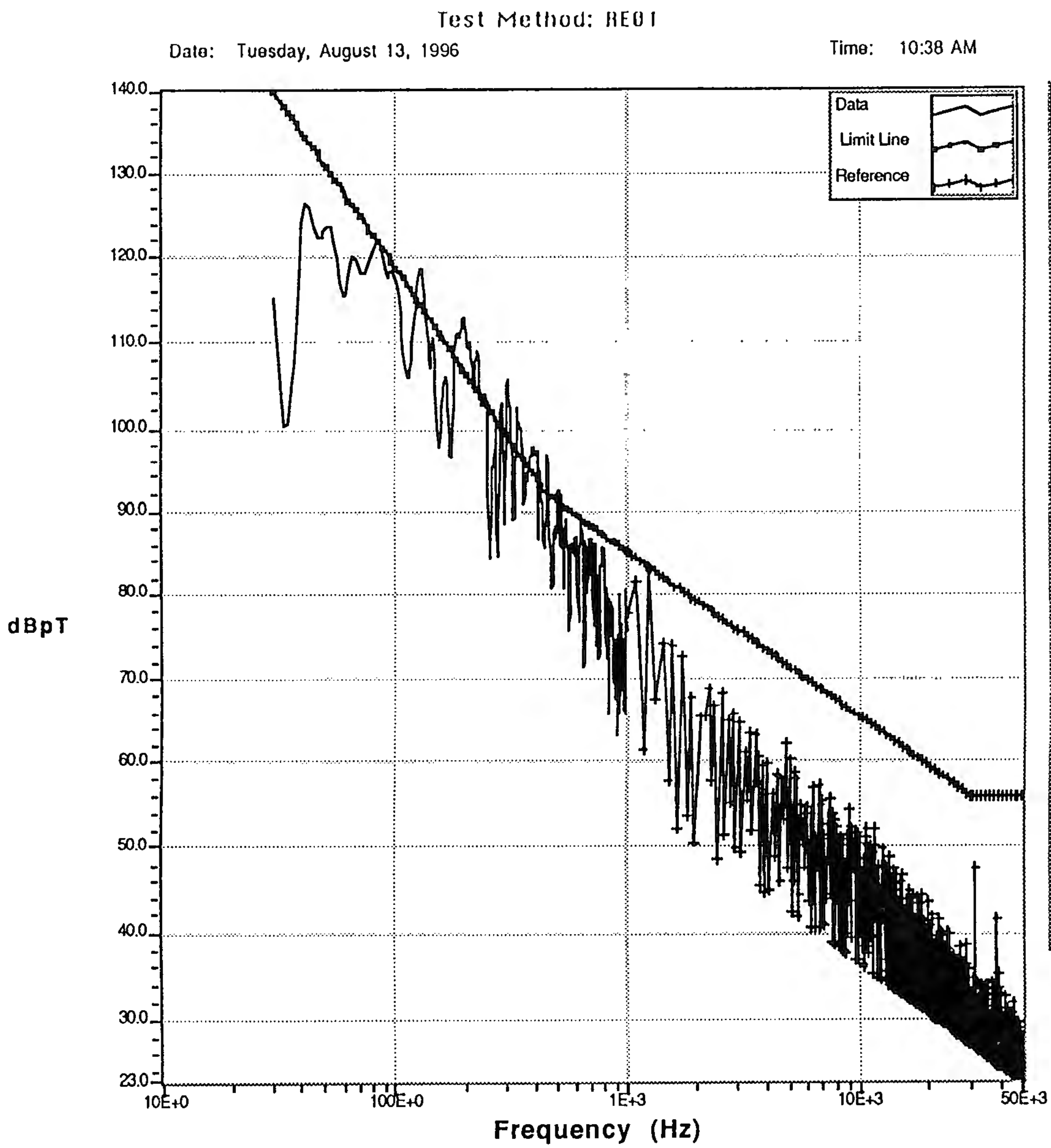
Test Info Table

8/22/95	4:55 PM
Car	Robins AFB DD2
Test site	Robins AFB, Training Site
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	10000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	10000

Remarks

front, 30 mph, horiz

Figure A-24. Dodge Dakota Vehicle in Open Field, E Field (30-1000 MHz) Taken at 1m from the Front Side



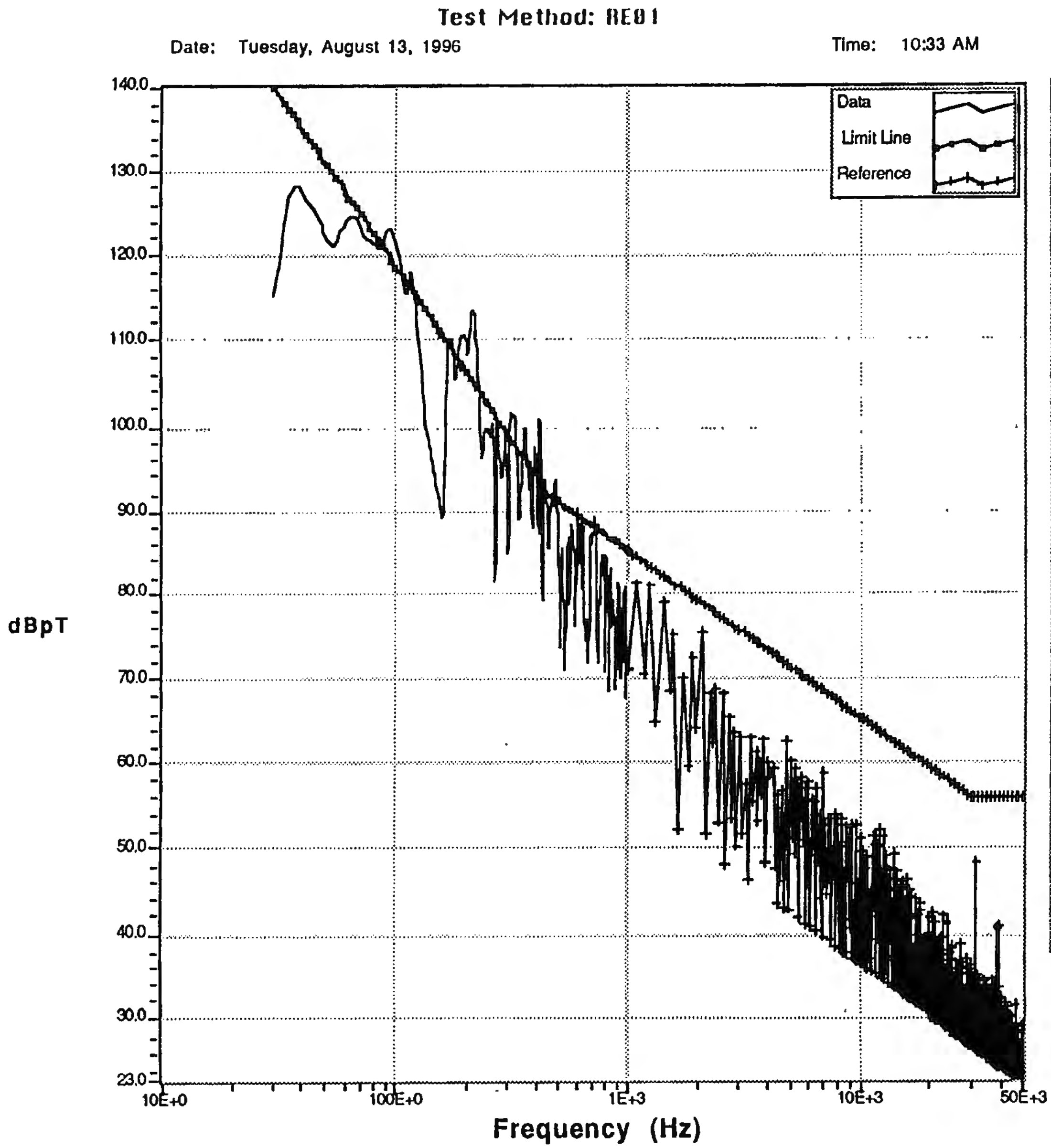
Test Info Table

9/22/95	2:26 PM
Car	Solectria Force
Test site	Fisher Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	EMCO 5 1/2" Loop SN 2163
Amplifier:	None
BandWidth:	1 0
Current Probe:	EMCO 5 1/2" Loop SN 2163
Amplifier:	None
BandWidth:	3 0

Remarks

Magnetic Field Measurement taken at Ambient Condition with Loop Antenna phasing 0 degrees

Figure A-25. Solectria Force Vehicle in Open Field, B Field Measurements Taken at Ambient Condition



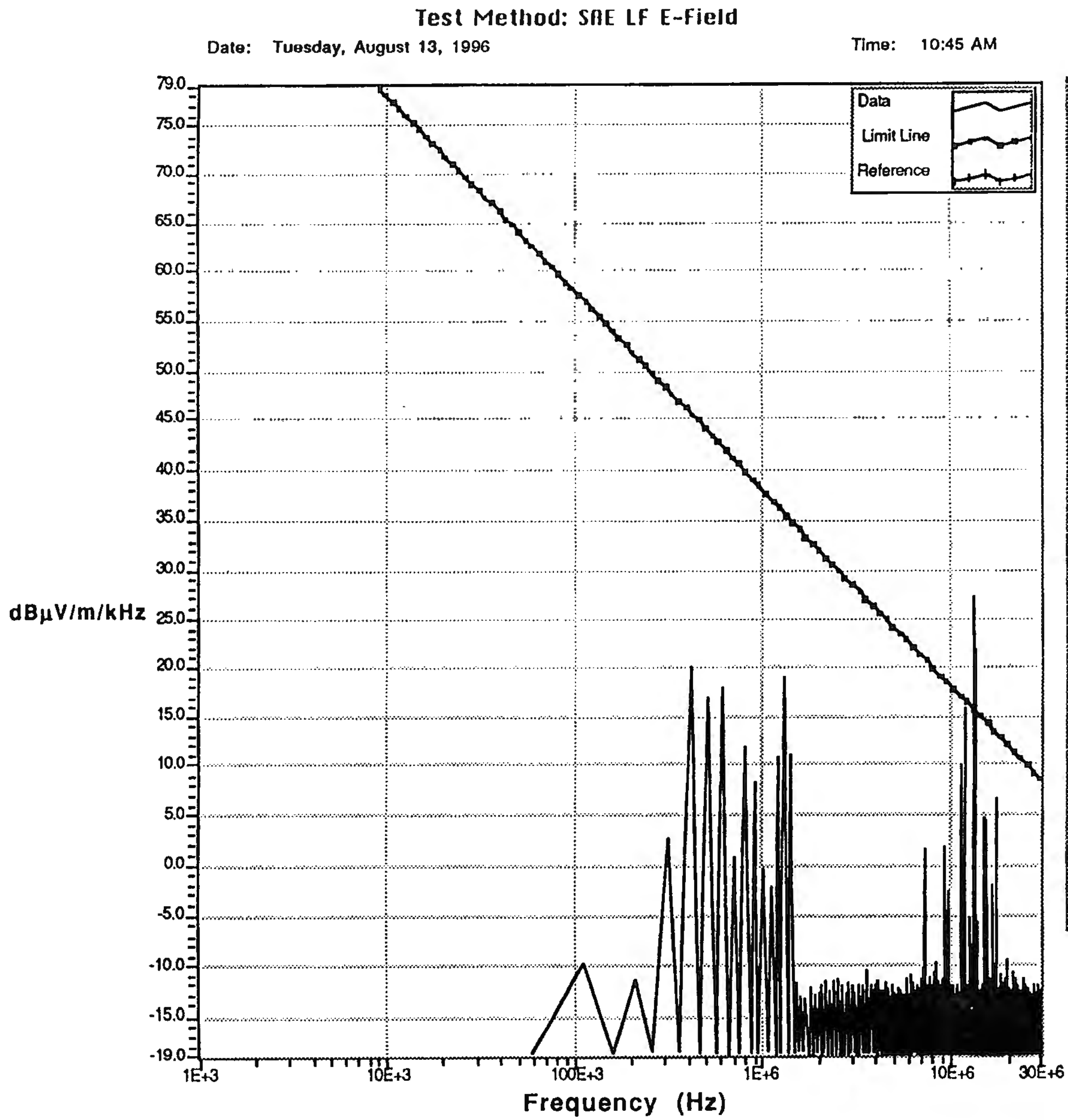
Test Info Table

9/22/95	6:11 PM
Car	Solectria Force
Test site	Fisher Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	EMCO 5 1/2" Loop SN 2163
Amplifier:	None
BandWidth:	1 0
Current Probe:	EMCO 5 1/2" Loop SN 2163
Amplifier:	None
BandWidth:	3 0

Remarks

Magnetic Field Measurement taken at 35 mph with Loop Antenna located at the Passenger seat and phasing 0 degrees

Figure A-26. Solectria Force Vehicle in Open Field, B Field Measurements Taken at the Passenger's Seat



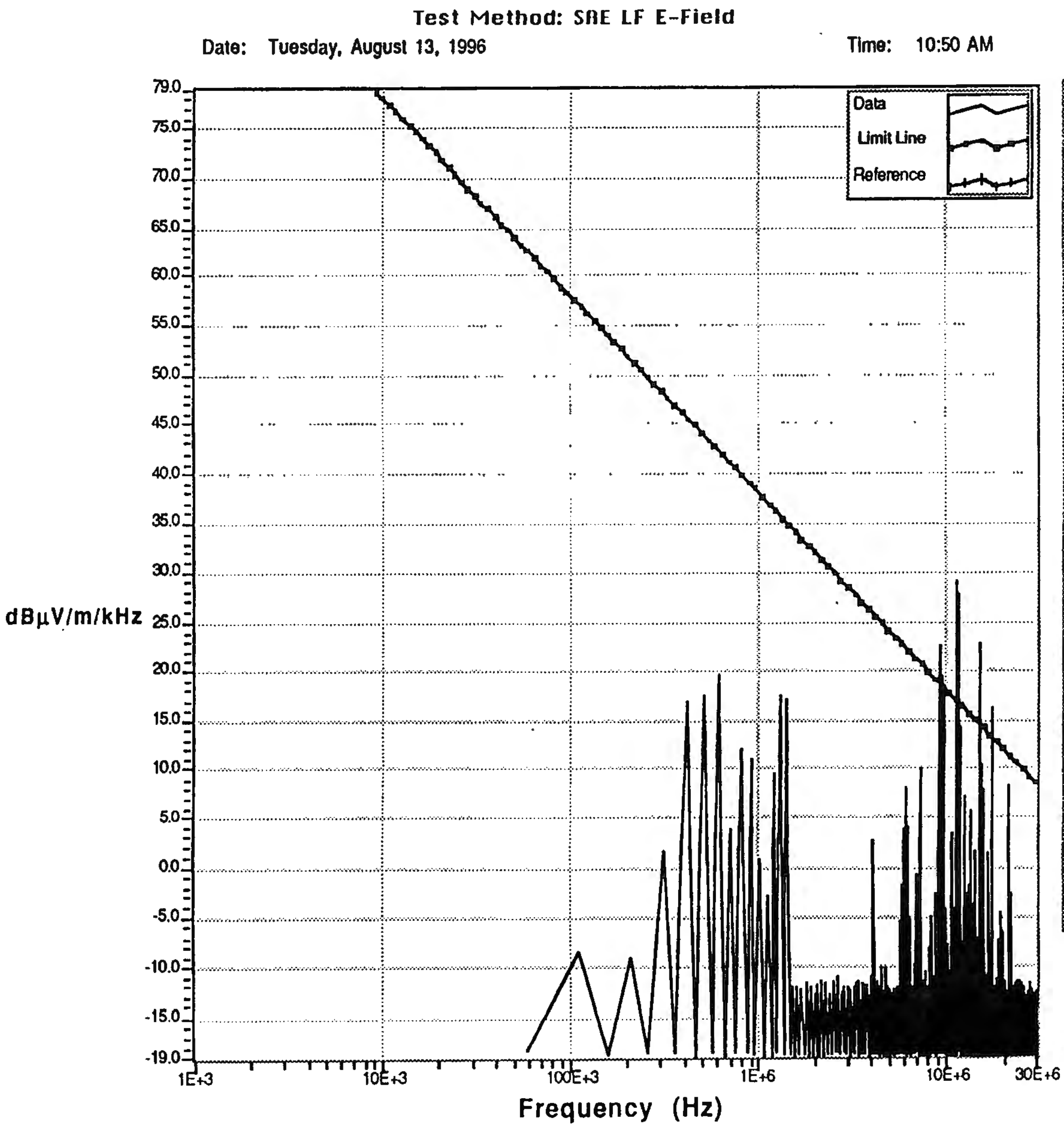
Test Info Table

9/22/95	2:15 PM
Car	Solectria Force
Test site	Fisher Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	BB Active MP SAS-200/550
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurement taken at Ambient Condition

Figure A-27. Solectria Force Vehicle in Open Field, E Field (0.009-30 MHz) Taken at Ambient Condition



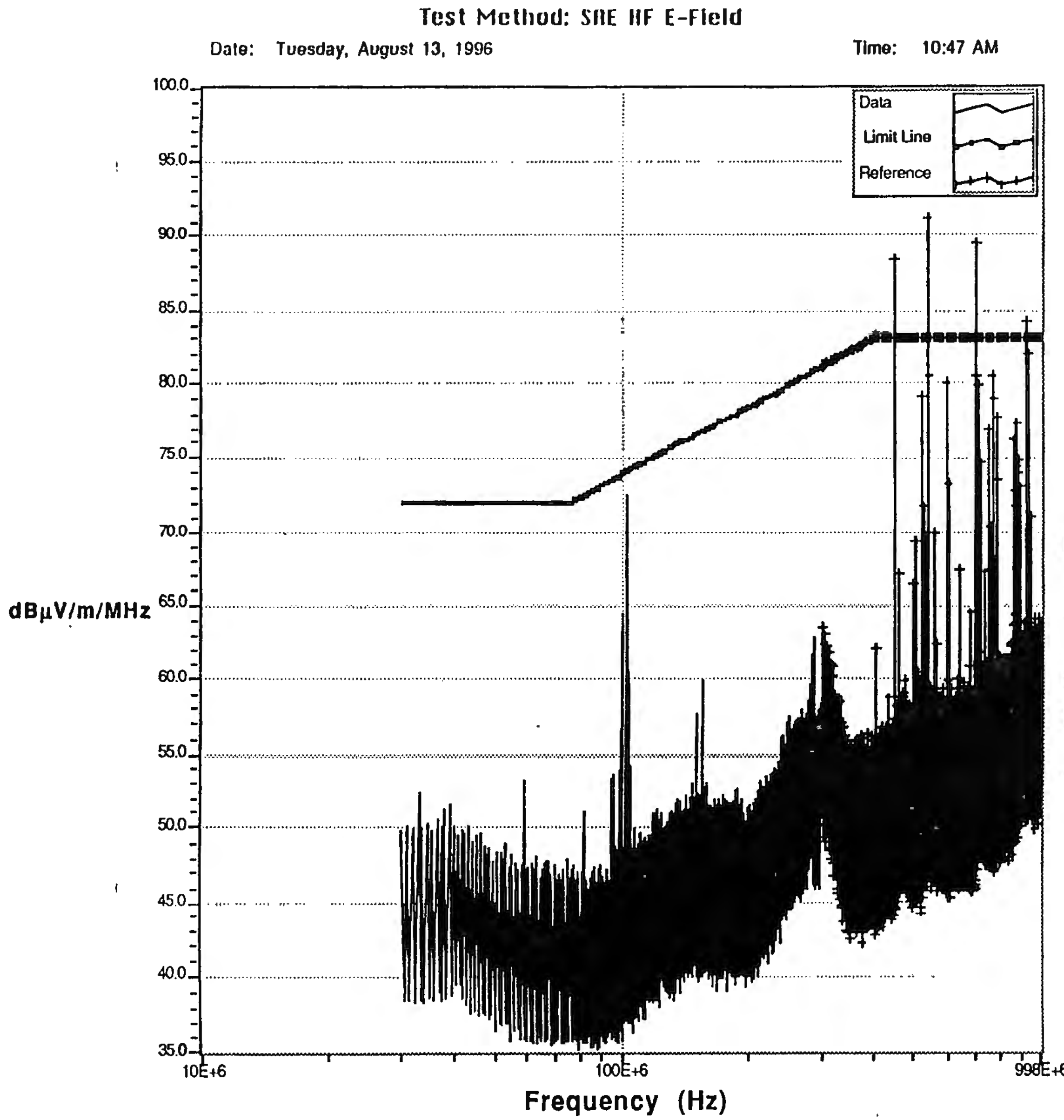
Test Info Table

9/22/95	4:54 PM
Car	Solectria Force
Test site	Fisher Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	BB Active MP SAS-200/550
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurement taken at 35 mph condition with car jacked up and antenna located at 10 m from the Front section of the car

Figure A-28. Solectria Force Vehicle in Open Field, E Field (0.009-30 MHz) Taken 10 m from the Front Side



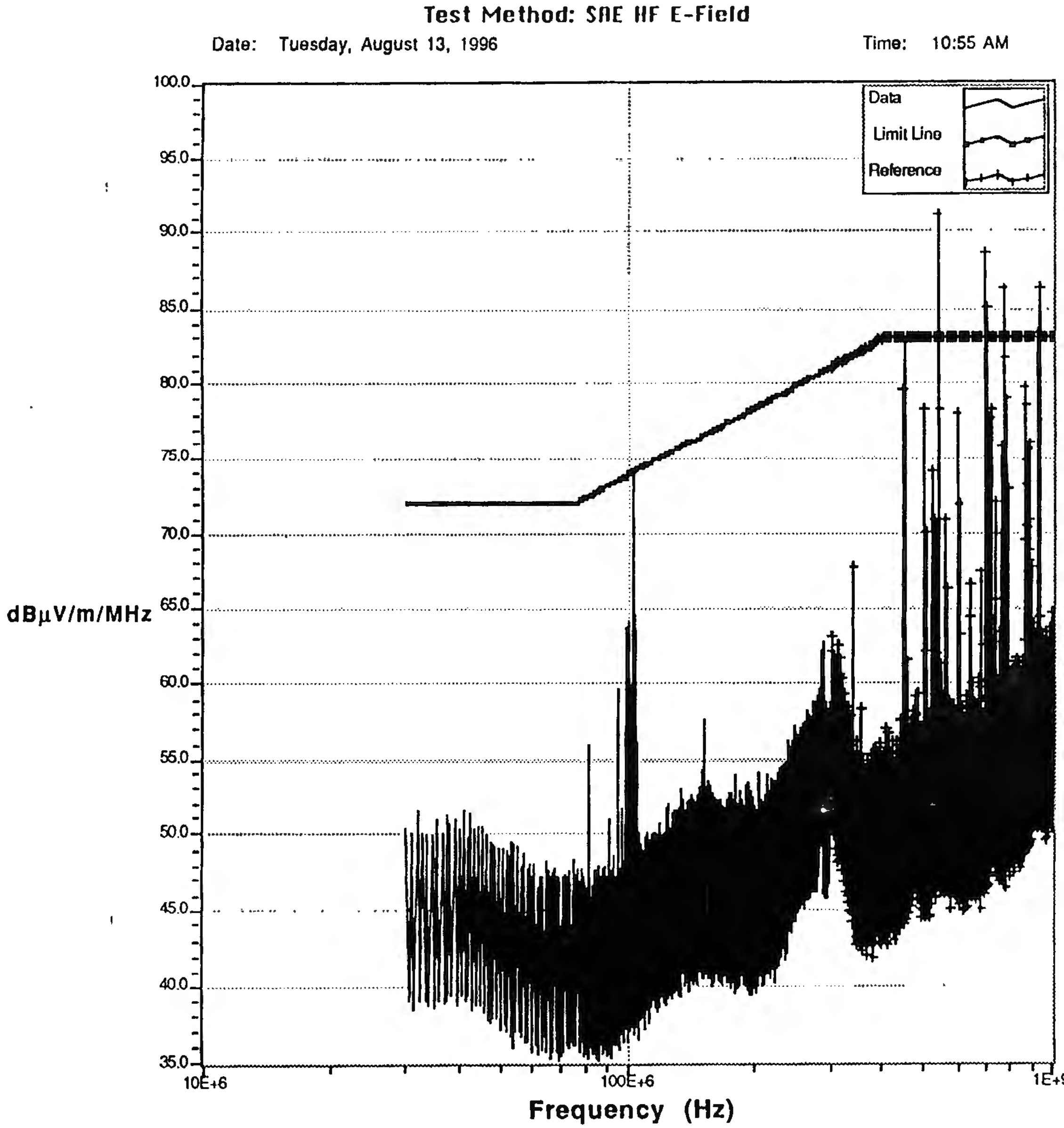
Test Info Table

9/22/95	2:17 PM
Car	Solectria Force
Test site	Fisher Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	10000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	10000

Remarks

Electric Field Measurement taken at Ambient Condition

Figure A-29. Solectria Force Vehicle in Open Field, E Field (30-1000 MHz) Taken at Ambient Condition



Test Info Table

9/22/95	4:57 PM
Car	Solectria Force
Test site	Fisher Island
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	10000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	10000

Remarks

Electric Field Measurement taken at 35 mph condition with car jacked up and antenna located at 10 m from the Front section of the car.
Antenna phase is Horizontal Polarization

Figure A-30. Solectria Force Vehicle in Open Field, E Field (30-1000 MHz) Taken 10 m from the Front Side

Dayton T. Brown Inc.

MIL-STD-461C RE01 CLASS A3

Date :	09/20/95	Time :	08:38:46.00	Detector	Peak	SPECS	
Technician :	V.Mirkov V.M.	Job Number	: 409175-00-000	Bandwidth	Per Table	1) MIL-STD-461C RE01	
Customer:	McLaughlin Research	Test Number	: 9175018	Impedence	50 Ohm	2)	
Test Item :	SOLECTRIA	Sensor Loc.	: Passenger side	RF Atten.	60 dB	3)	
Mode of Op. :	Ambient	Sensor Pol.	:	High Pass	16 Hz	4)	
Serial No. :	PROTOTYPE	Ext. Atten.	: 0 dB	Low Pass	50 kHz		
				Output	IF		

EMC-11 SETTINGS

Comment :

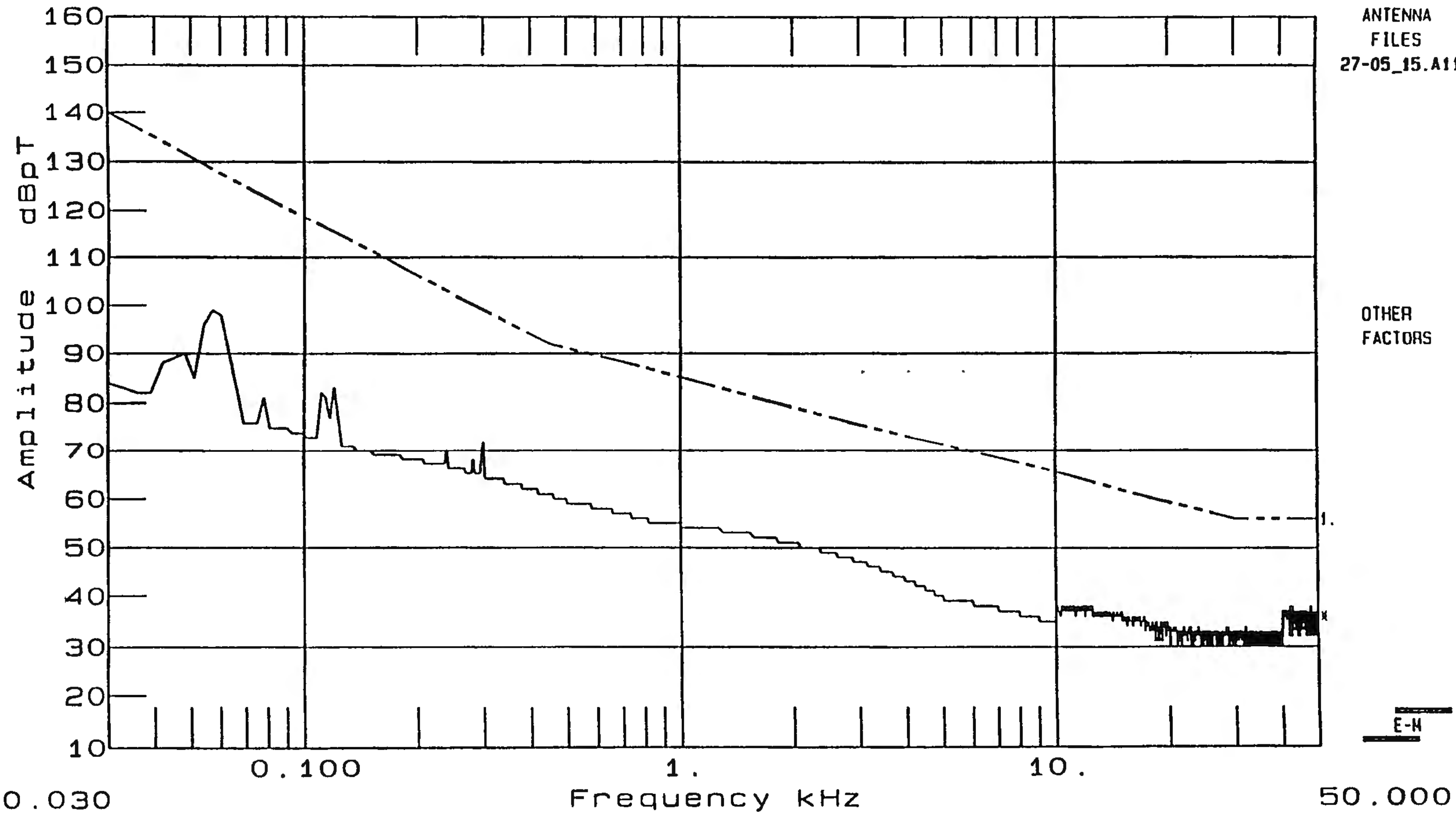


Figure A-31. Solectria Force Vehicle in Anechoic Room, B Field Measurements Taken at Ambient Condition

Dayton T. Brown Inc.

MIL-STD-461C RE01 CLASS A3

Date : 09/20/95
Technician : V.Mirkov V.M
Customer: McLaughlin Research
Test Item : SOLECTRIA
Mode of Op. : Drive
Serial No. : PROTOTYPE

Time : 08:21:08.79
Job Number : 409175-00-000
Test Number : 9175017
Sensor Loc. : Passenger side
Sensor Pol. :
Ext. Atten. : 0 dB

EMC-11 SETTINGS
Detector Peak
Bandwidth Per Table
Impedence 50 Ohm
RF Atten. 60 dB
High Pass 16 Hz
Low Pass 50 kHz
Output IF

SPECS
1) MIL-STD-461C RE01
2)
3)
4)

R. [signature]

Comment :

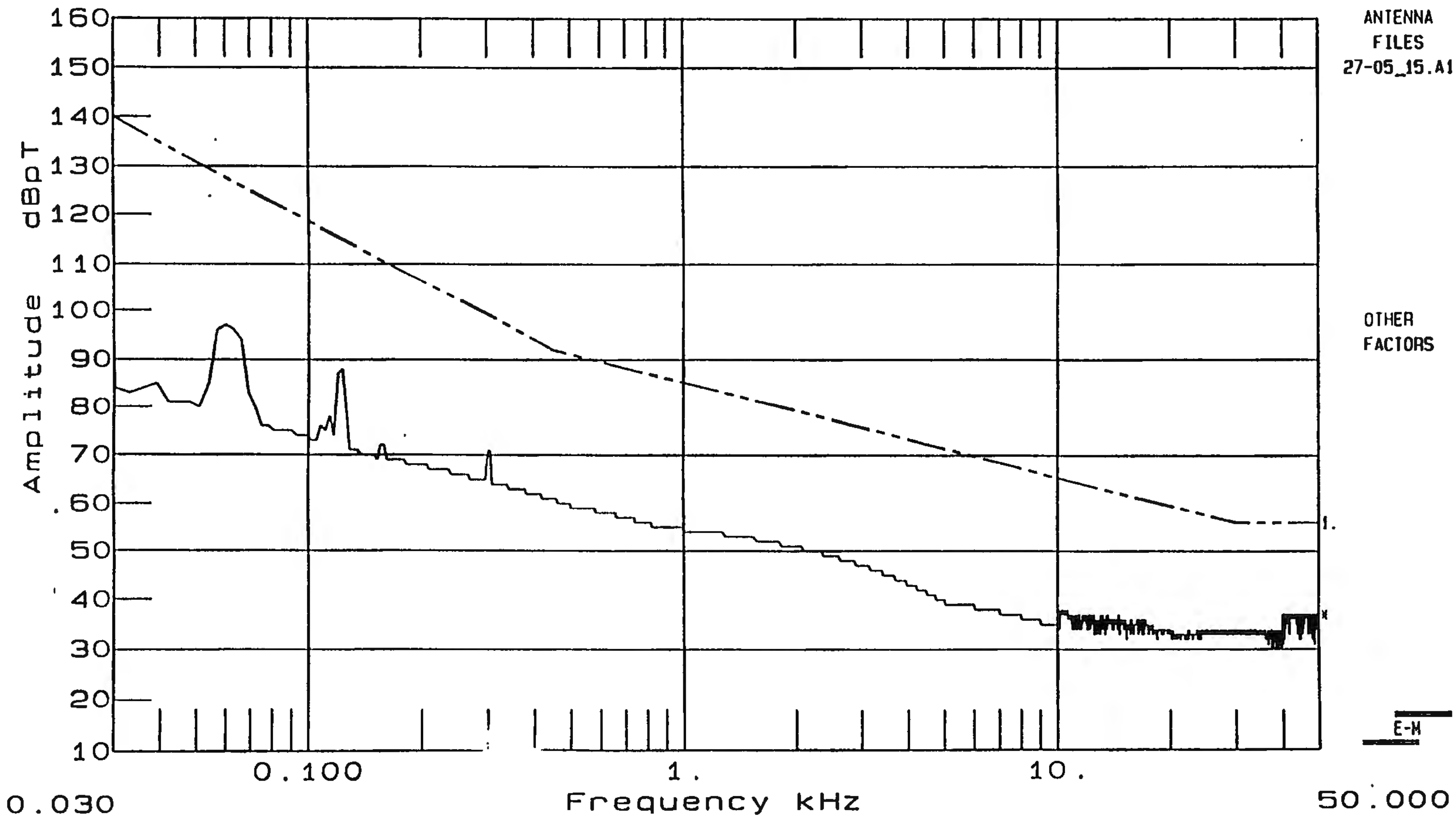


Figure A-32. Solectria Force Vehicle in Anechoic Room, B Field Measurements Taken at the Passenger's Side

Dayton T. Brown Inc.

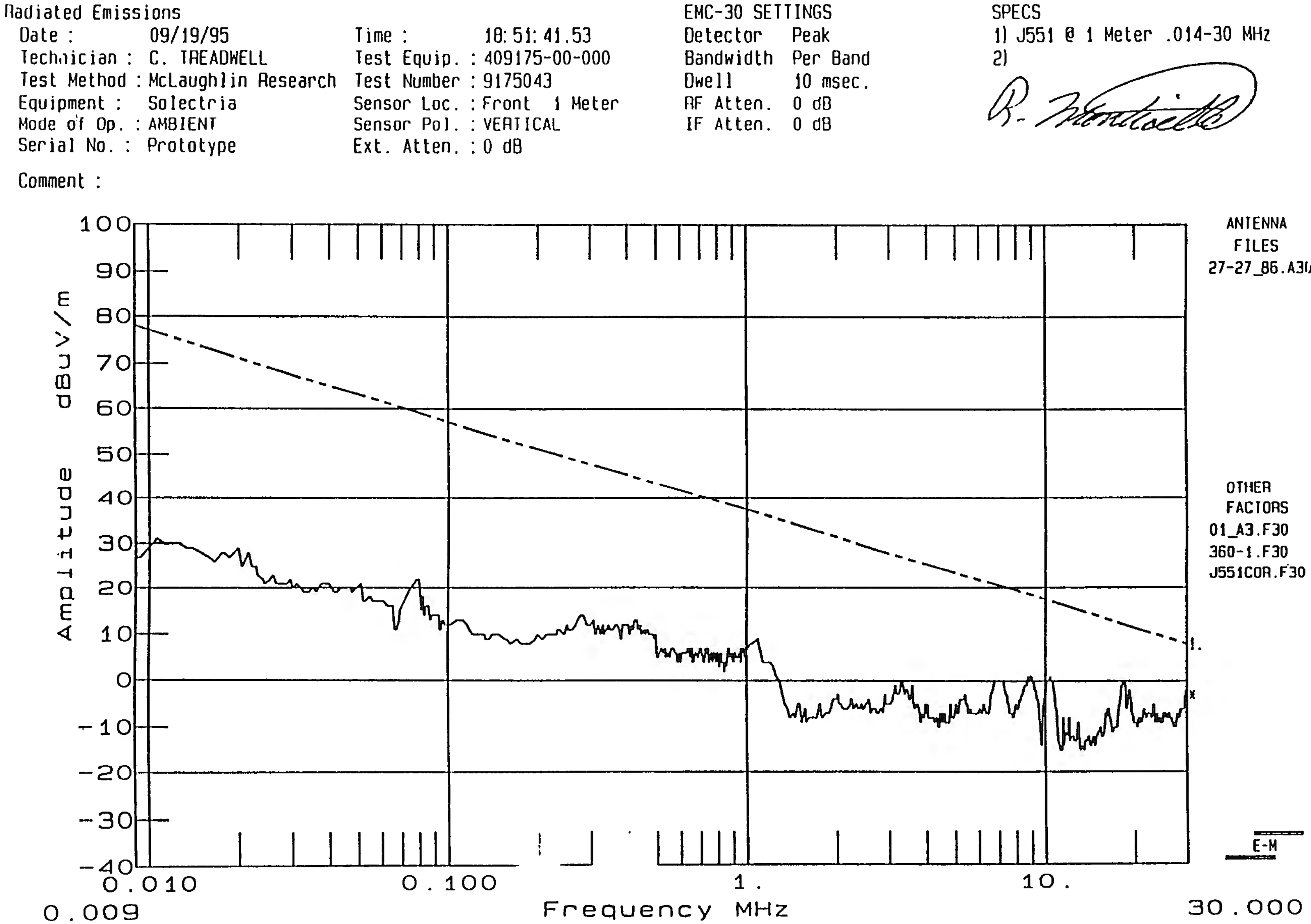


Figure A-33. Solectria Force Vehicle in Anechoic Room, E Field (0.009-30 MHz) Taken at Ambient Condition

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/19/95	Time :	15:30:23.68	EMC-30 SETTINGS		SPECS	
Technician :	V.Mirkov V.M.	Test Equip. :	409175-00-000	Detector	Peak	1) J551 @ 1 Meter .014-30 MHz	
Test Method :	McLaughlin Research	Test Number :	9175030	Bandwidth	Per Band	2)	
Equipment :	Solectria	Sensor Loc. :	Front 1 Meter	Dwell	10 msec.		
Mode of Op. :	Drive	Sensor Pol. :	VERTICAL	RF Atten.	0 dB		
Serial No. :	Prototype	Ext. Atten. :	0 dB	IF Atten.	0 dB		

Comment : Unloaded

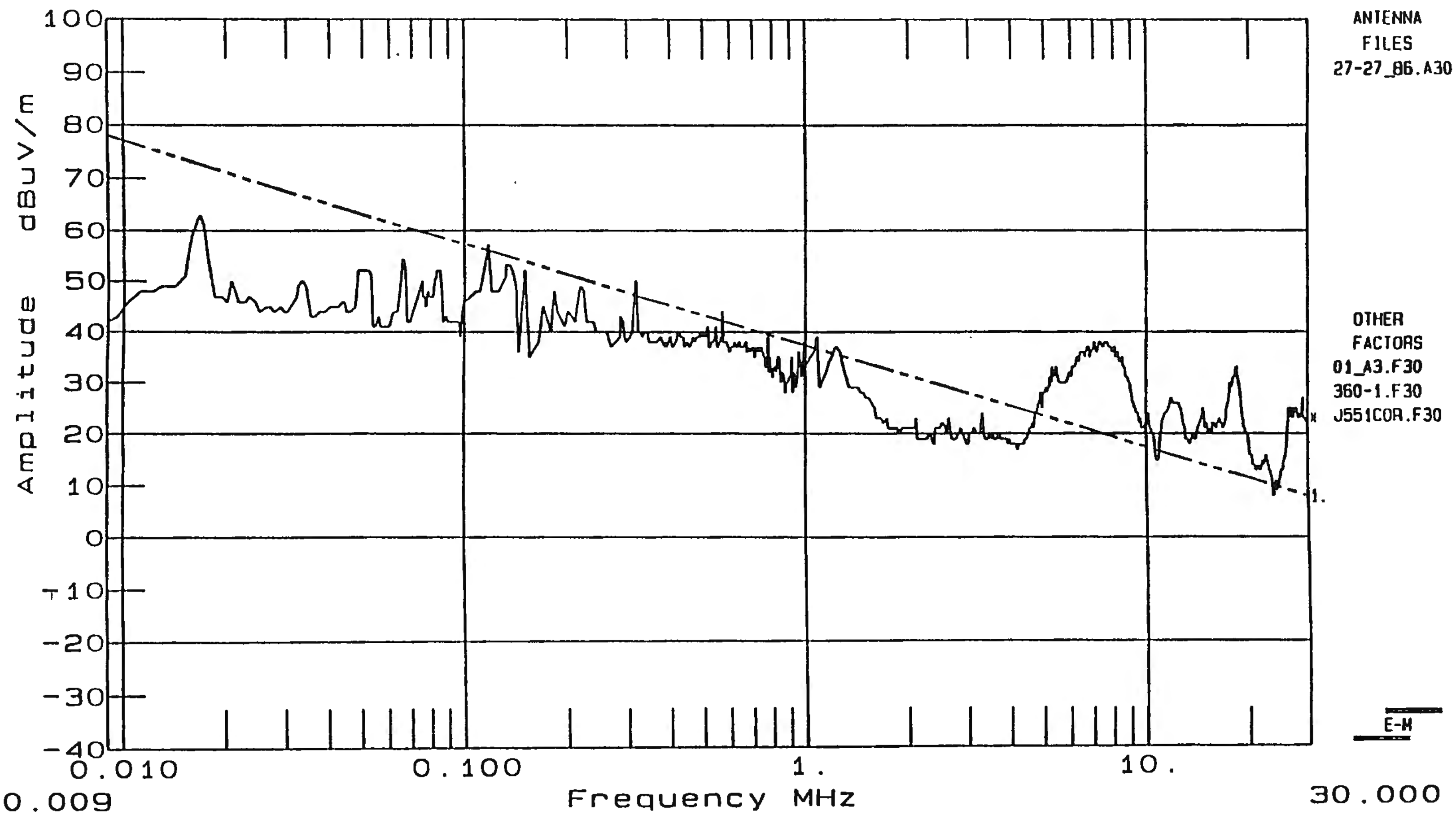


Figure A-34. Solectria Force Vehicle in Anechoic Room, E Field (0.009-30 MHz) Taken 1m from the Front Side

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/19/95	Time :	21:08:00.04	EMC-30 SETTINGS		SPECS	
Technician :	C. TREADWELL	Test Equip. :	409175-00-000	Detector	Peak	1) J551 @ 1 Meter	
Test Method :	McLaughlin Research	Test Number :	9175044	Bandwidth	Per Band	2)	
Equipment :	Solectria	Sensor Loc. :	1m IN FRONT	Dwell	10 msec.		
Mode of Op. :	AMBIENT	Sensor Pol. :	HORIZONTAL	RF Atten.	0 dB		
Serial No. :	Prototype	Ext. Atten. :	0 dB	IF Atten.	0 dB		

Comment :

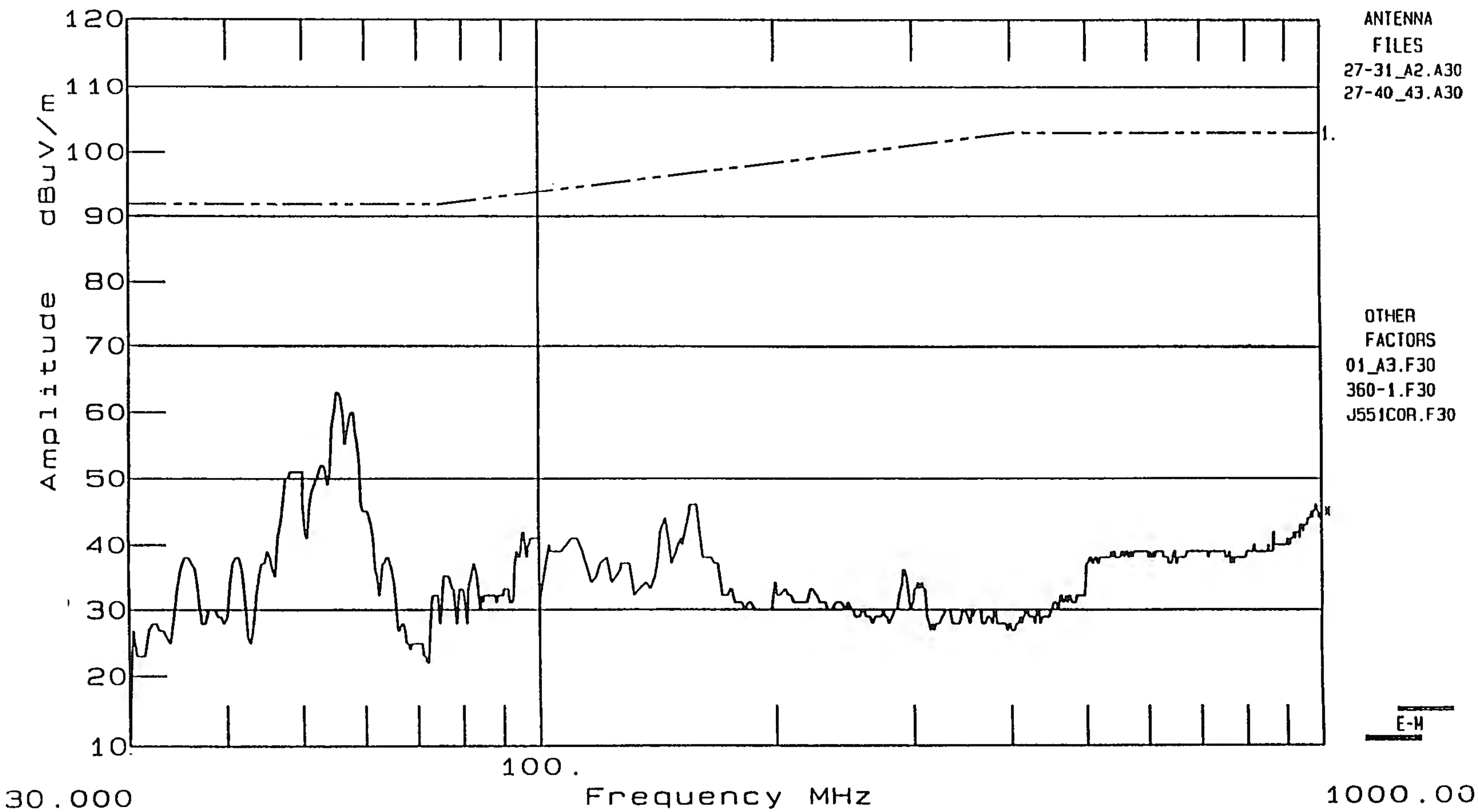


Figure A-35. Solectria Force Vehicle in Anechoic Room, E Field (30-1000 MHz) Taken at Ambient Condition

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/19/95	Time :	17:53:48.09	EMC-30 SETTINGS		SPECS	
Technician :	C. TREADWELL	Test Equip. :	409175-00-000	Detector	Peak	1) J551 @ 1 Meter	
Test Method :	McLaughlin Research	Test Number :	9175040	Bandwidth	Per Band	2)	
Equipment :	Solectria	Sensor Loc. :	1m IN FRONT	Dwell	10 msec.	R. Treadwell	
Mode of Op. :	DRIVE	Sensor Pol. :	HORIZONTAL	RF Atten.	0 dB		
Serial No. :	Prototype	Ext. Atten. :	0 dB	IF Atten.	0 dB		

Comment : UNLOADED

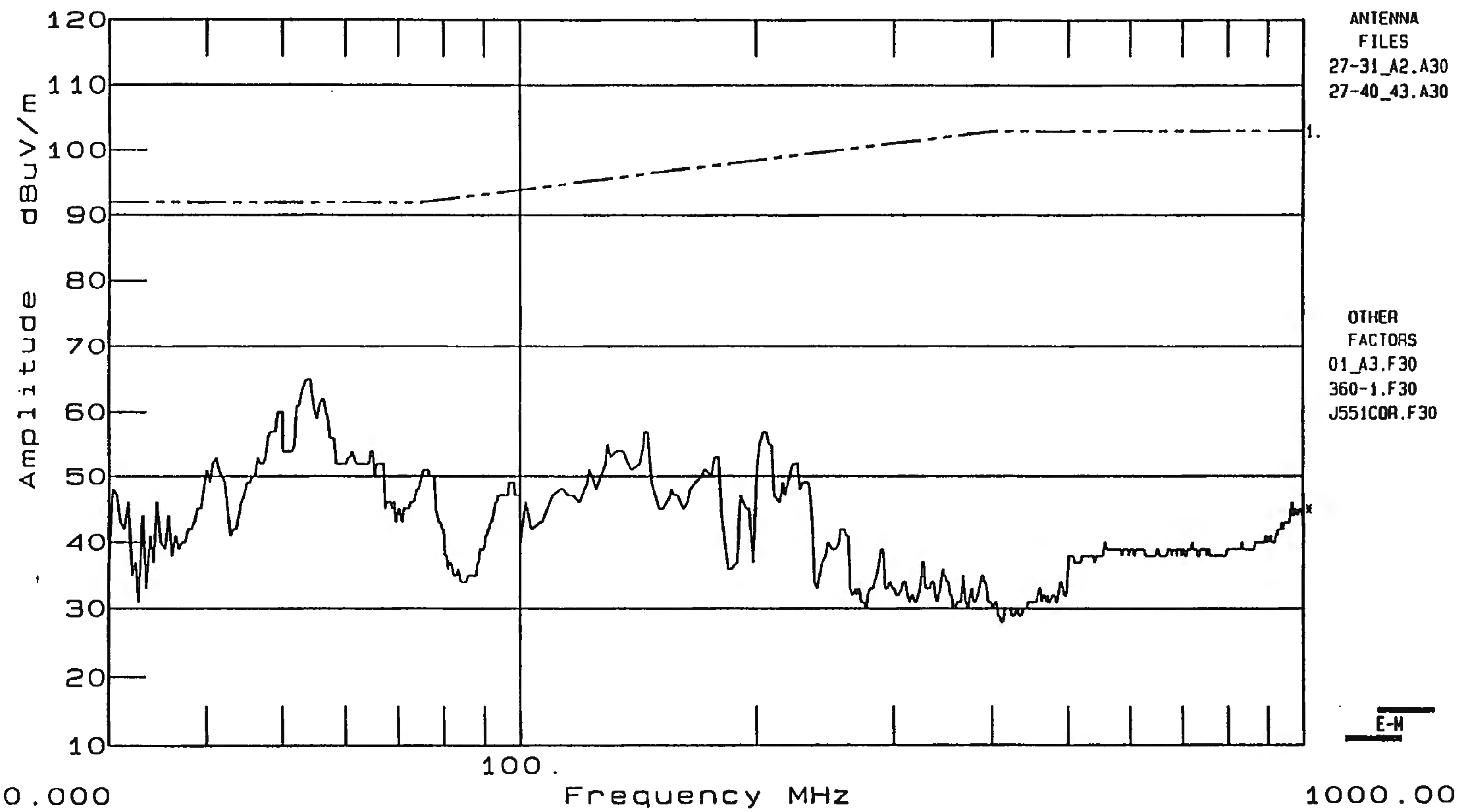


Figure A-36. Solectria Force Vehicle in Anechoic Room, E Field (30-1000 MHz) Taken 1m from the Front Side

Dayton T. Brown Inc.

MIL-STD-461C RE01 CLASS A3

Date :	09/20/95	Time :	15:05:48.17	EMC-11 SETTINGS		SPECS
Technician :	V.Mirkov *V.M.*	Job Number	: 409175-00-000	Detector	Peak	1) MIL-STD-461C RE01
Customer:	McLaughlin Research	Test Number	: 9175024	Bandwidth	Per Table	2)
Test Item :	Gas Powered car	Sensor Loc.	: Driver side floor	Impedence	50 Ohm	3)
Mode of Op. :	Ambient	Sensor Pol.	:	RF Atten.	60 dB	4)
Serial No. :	PROTOTYPE	Ext. Atten.	: 0 dB	High Pass	16 Hz	
				Low Pass	50 kHz	
				Output	IF	

Comment :

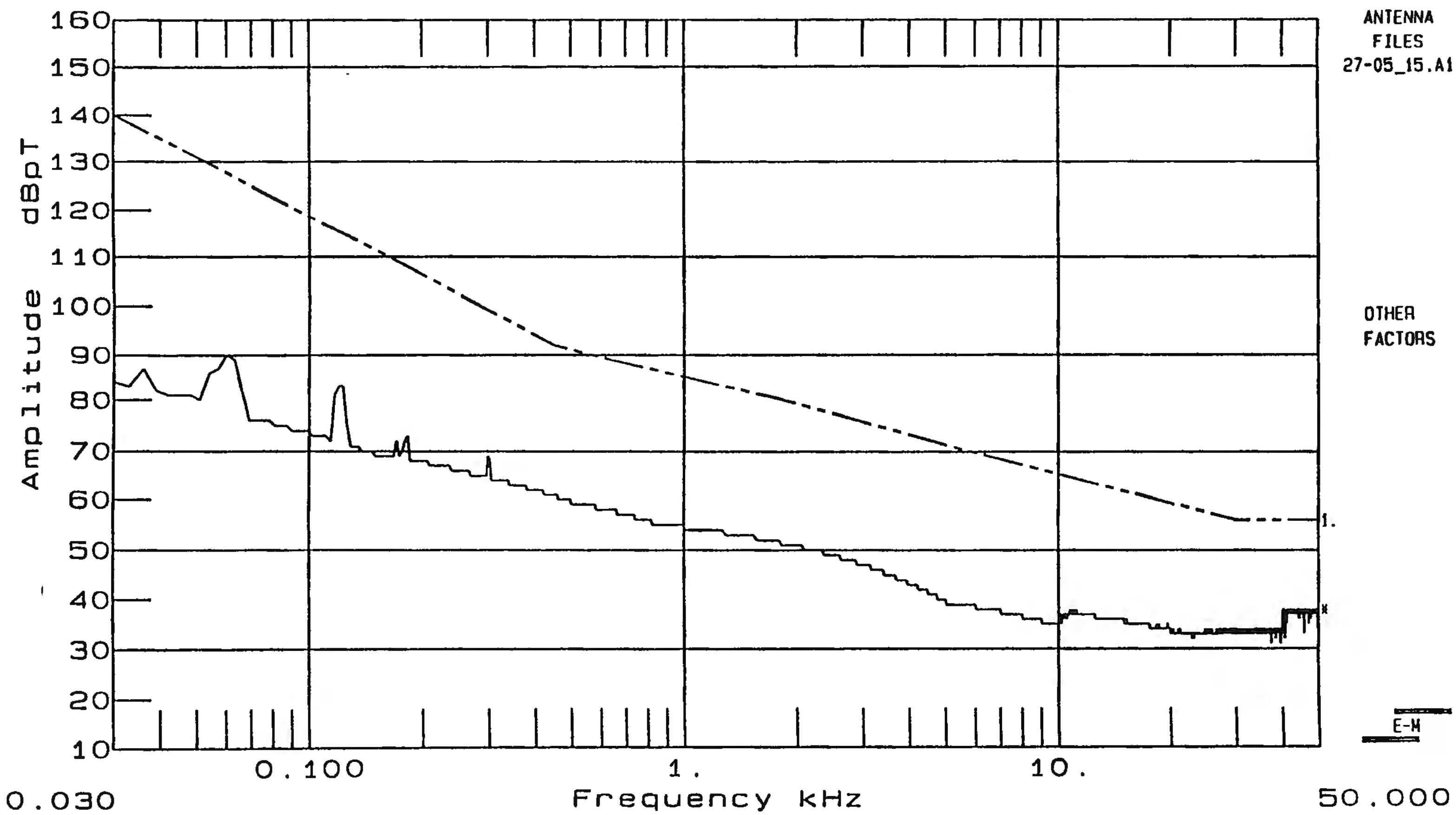


Figure A-37. Solectria ICE Vehicle in Anechoic Room, B Field Measurements Taken at Ambient Condition

Dayton T. Brown Inc.

MIL-STD-461C RE01 CLASS A3

Date : 09/20/95
Technician : V.Mirkov V.M.
Customer: McLaughlin Research
Test Item : Gas Powered car
Mode of Op. : Drive
Serial No. : PROTOTYPE
Comment :

Time : 14:32:49.31
Job Number : 409175-00-000
Test Number : 9175022
Sensor Loc. : Driver side
Sensor Pol. :
Ext. Atten. : 0 dB

EMC-11 SETTINGS
Detector Peak
Bandwidth Per Table
Impedence 50 Ohm
RF Atten. 60 dB
High Pass 16 Hz
Low Pass 50 kHz
Output IF

SPECS
1) MIL-STD-461C RE01
2)
3)
4)

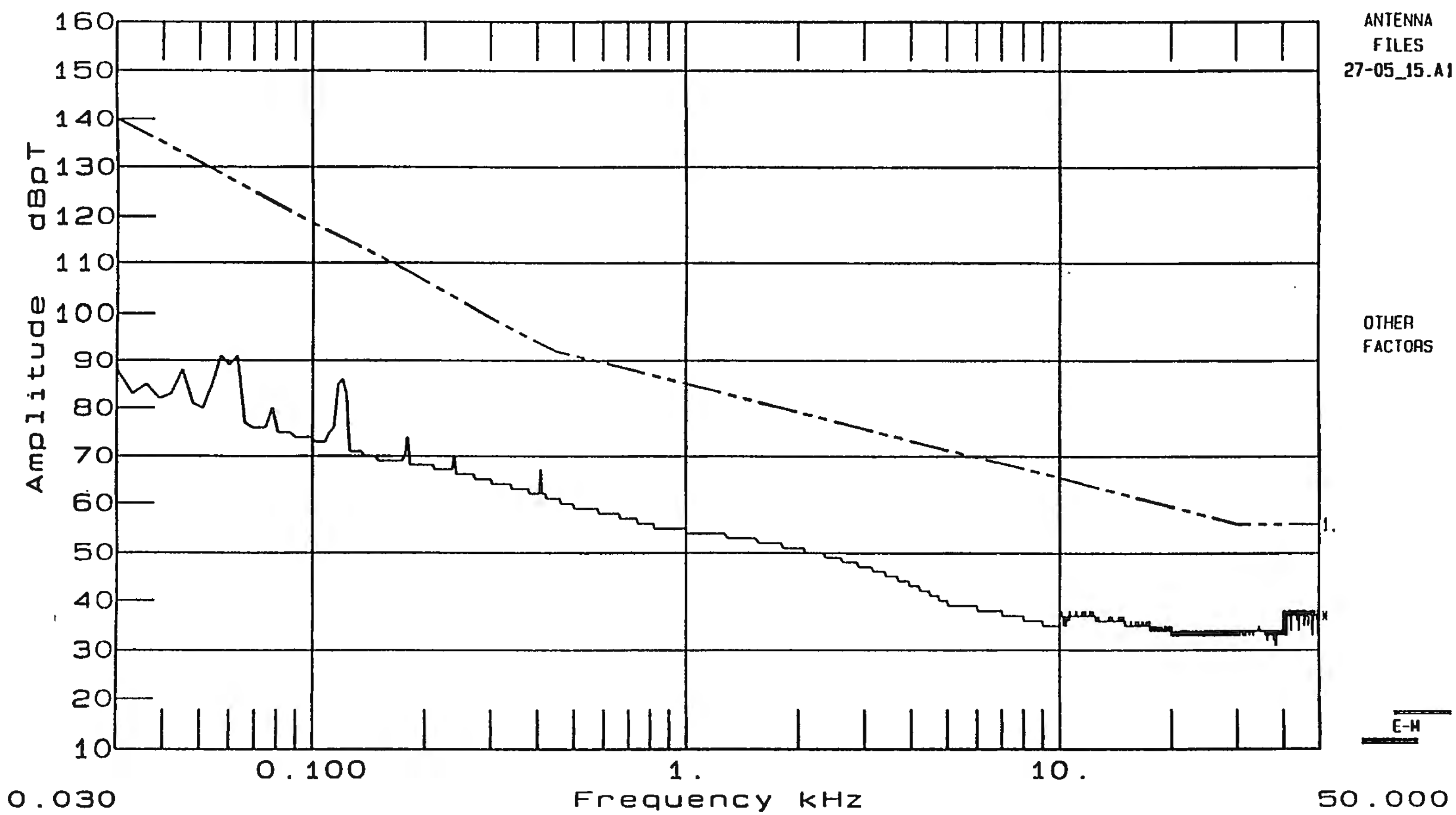


Figure A-38. Solectria ICE Vehicle in Anechoic Room, B Field Measurements Taken at the Driver's Side

Dayton T. Brown Inc.

Radiated Emissions

Date : 09/20/95
Technician : V.Mirkov V.M.
Customer : McLaughlin Research
Test Item : Gas powered car
Mode of Op. : Ambient
Serial No. : 2C1MR5292S6783748

Time : 16:36:10.19
Job Number : 409175-00-000
Test Number : 9175051
Sensor Loc. : Front 1 Meter
Sensor Pol. : VERTICAL
Ext. Atten. : 0 dB

EMC-30 SETTINGS
Detector Peak
Bandwidth Per Band
Dwell 10 msec.
RF Atten. 0 dB
IF Atten. 0 dB

SPECS
1) J551 @ 1 Meter .014-30 MHz
2)

Comment : .

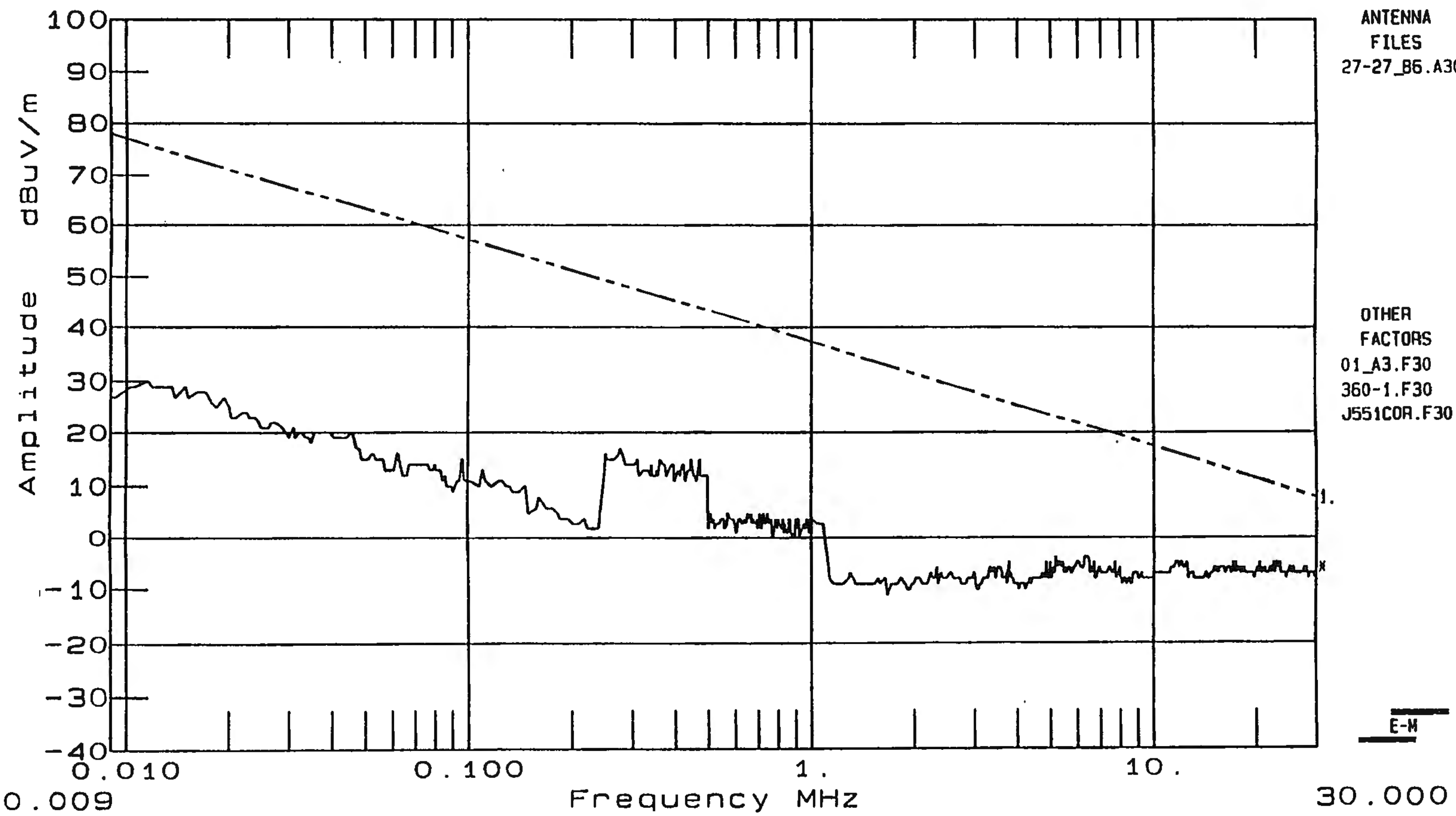


Figure A-39. Solectria ICE Vehicle in Anechoic Room, E Field (0.009-30 MHz) Taken at Ambient Condition

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/20/95	Time :	16:05:30.68	EMC-30 SETTINGS		SPECS	
Technician :	V.Mirkov V.M.	Job Number :	409175-00-000	Detector	Peak	1) J551 @ 1 Meter .014-30 MHz	
Customer :	McLaughlin Research	Test Number :	9175050	Bandwidth	Per Band	2)	
Test Item :	Gas powered car	Sensor Loc. :	Front 1 Meter	Dwell	10 msec.		
Mode of Op. :	Drive	Sensor Pol. :	VERTICAL	RF Atten.	0 dB		
Serial No. :	2C1MR5292S6783748	Ext. Atten. :	0 dB	IF Atten.	0 dB		

Comment : Unloaded 25Mph

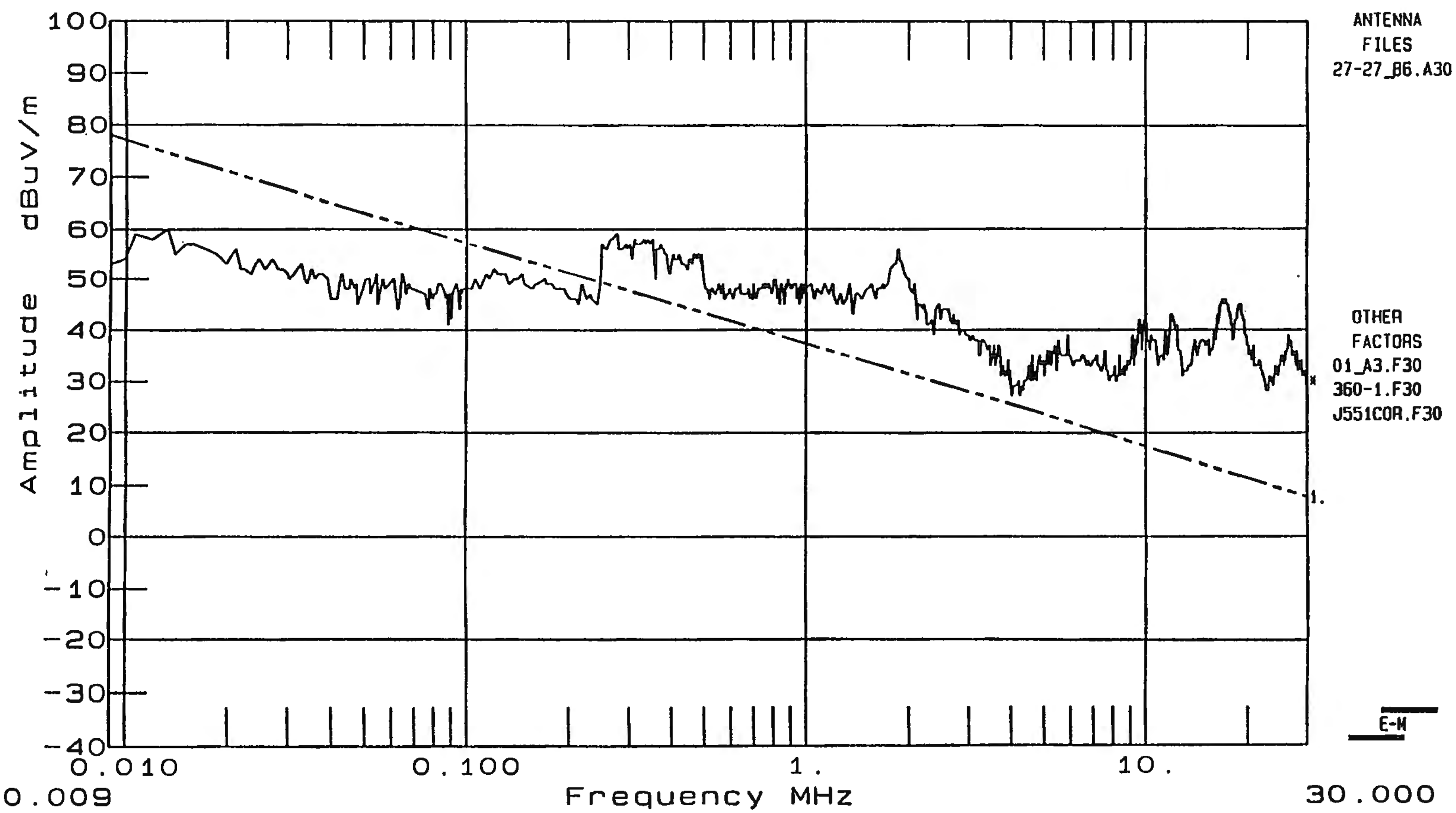


Figure A-40. Solectria ICE Vehicle in Anechoic Room, E Field (0.009-30 MHz) Taken 1m from the Front Side

Dayton T. Brown Inc.

Radiated Emissions

Date :	09/20/95	Time :	22:50:00.88	EMC-30 SETTINGS		SPECS
Technician :	C. Treadwell	Job Number	: 409175-00-000	Detector	Peak	1) J551 @ 1 Meter
Customer	: McLaughlin Research	Test Number	: 9175061	Bandwidth	Per Band	2)
Test Item :	Gas powered car	Sensor Loc.	: IN FRONT	Dwell	20 msec.	
Mode of Op. :	AMBIENT	Sensor Pol.	: HORIZONTAL	RF Atten.	0 dB	
Serial No. :	2C1MA529S6783748	Ext. Atten.	: 0 dB	IF Atten.	0 dB	DATA FILE : 9175061.D31

Comment :

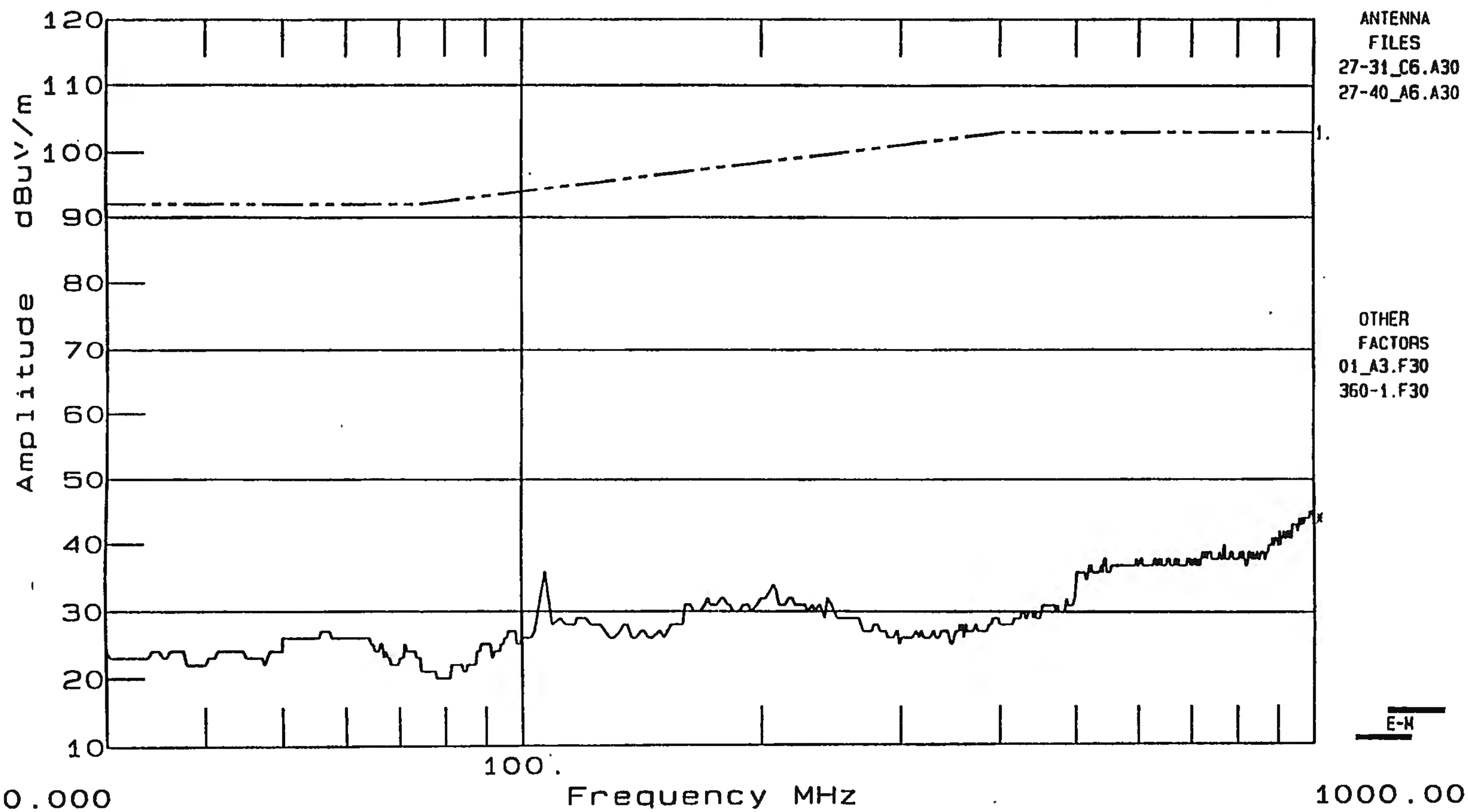


Figure A-41. Solectria ICE Vehicle in Anechoic Room, E Field (30-1000 MHz) Taken at Ambient Condition

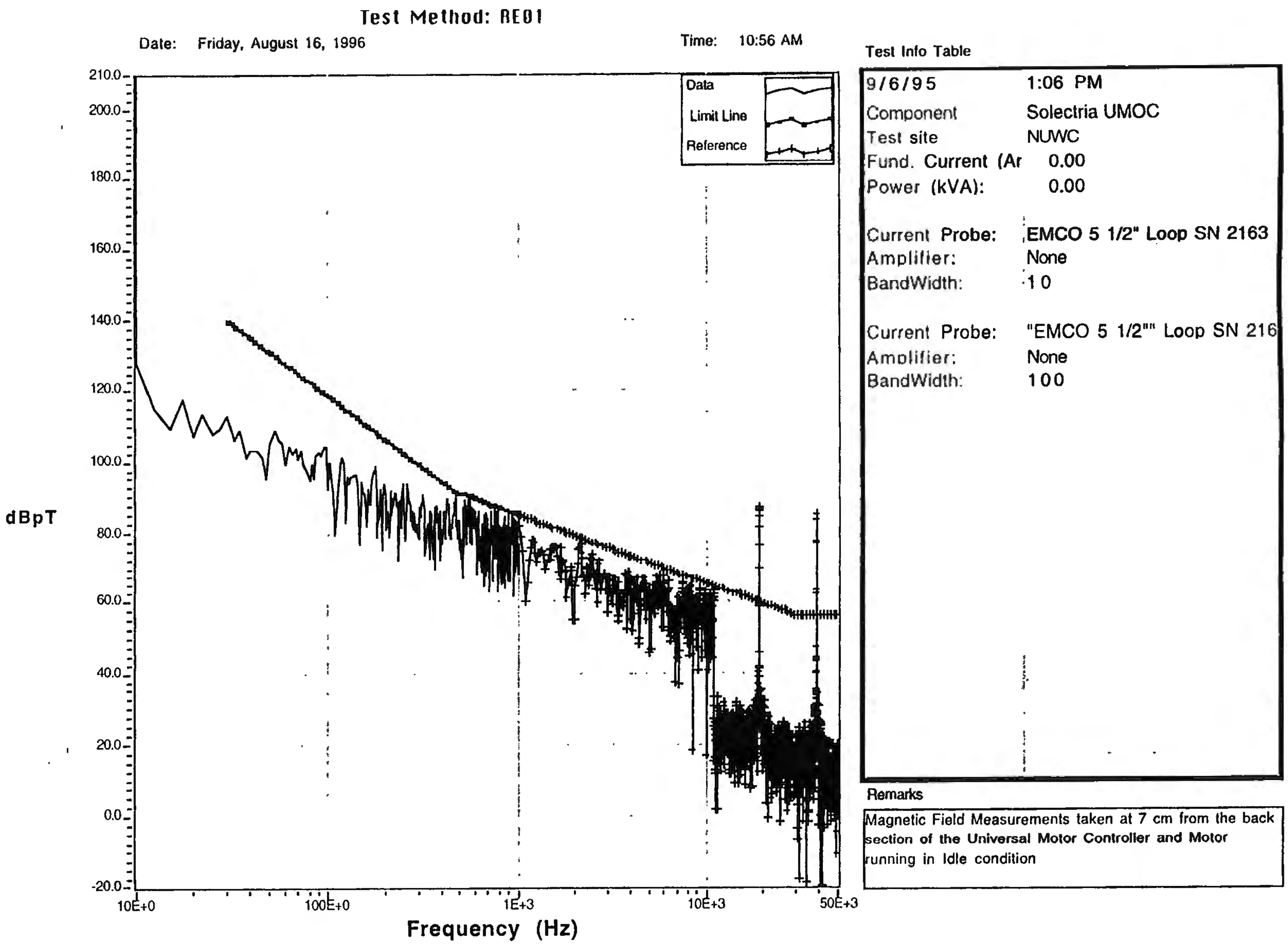


Figure A-42. Solectria ICE Vehicle in Anechoic Room, E Field (30-1000 MHz) Taken 1m from the Front Side

Dayton T. Brown Inc.

Radiated Emissions

Date : 09/20/95
Technician : C. Treadwell
Customer : McLaughlin Research
Test Item : Gas powered car
Mode of Op. : Drive
Serial No. : 2C1MR529S6783748

Time : 19:51:10.64
Job Number : 409175-00-000
Test Number : 9175059
Sensor Loc. : IN FRONT
Sensor Pol. : HORIZONTAL
Ext. Atten. : 0 dB

EMC-30 SETTINGS
Detector Peak
Bandwidth Per Band.
Dwell 20 msec.
RF Atten. 0 dB
IF Atten. 0 dB

SPECS
1) J551 @ 1 Meter
2)

DATA FILE : 9175059.D31

Comment : TEST ITEM NOT LOADED 25 MPH.

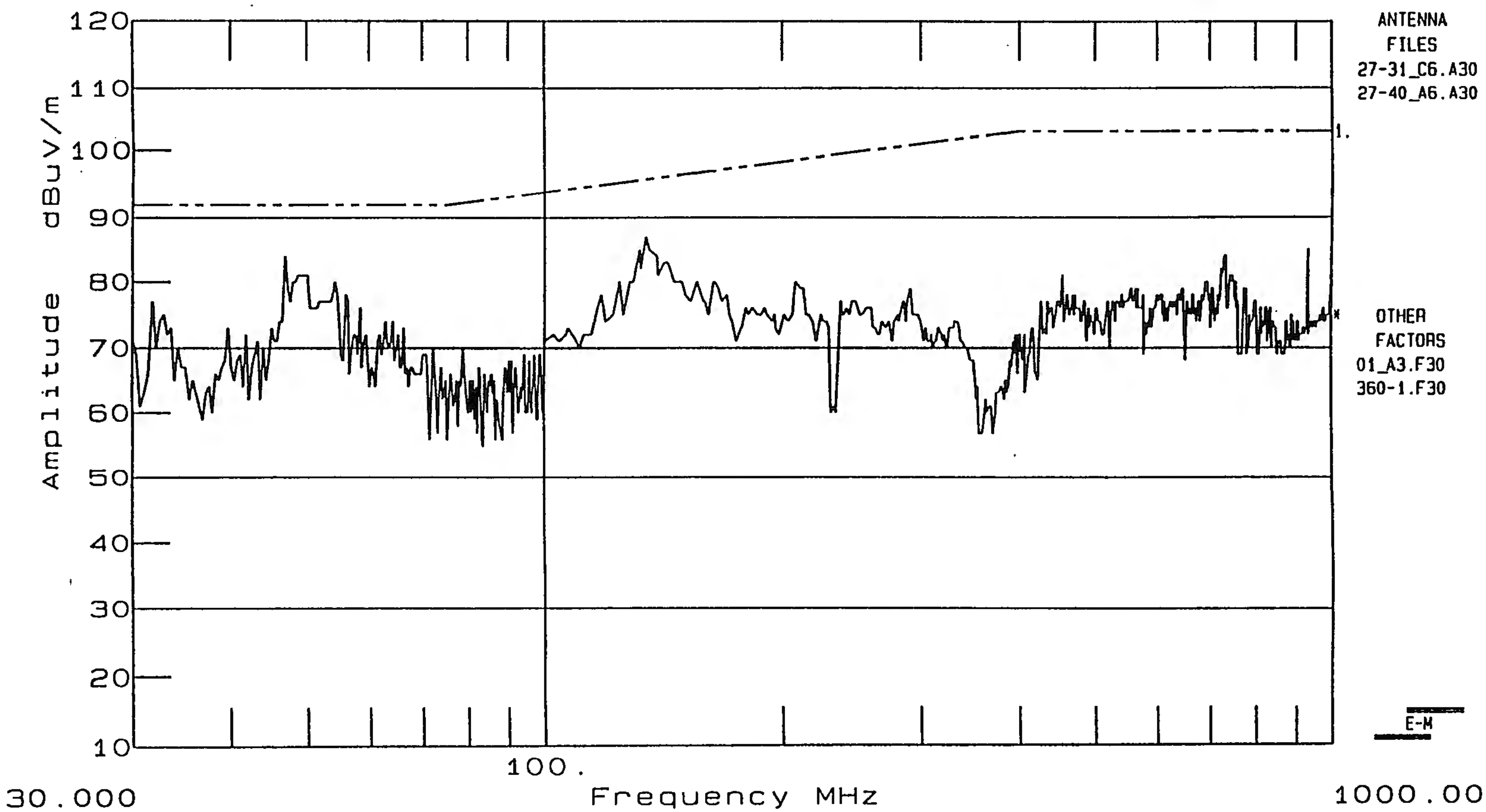


Figure A-43. Solectria Motor Controller in Anechoic Room, B Field Measurements Taken at Idle Condition

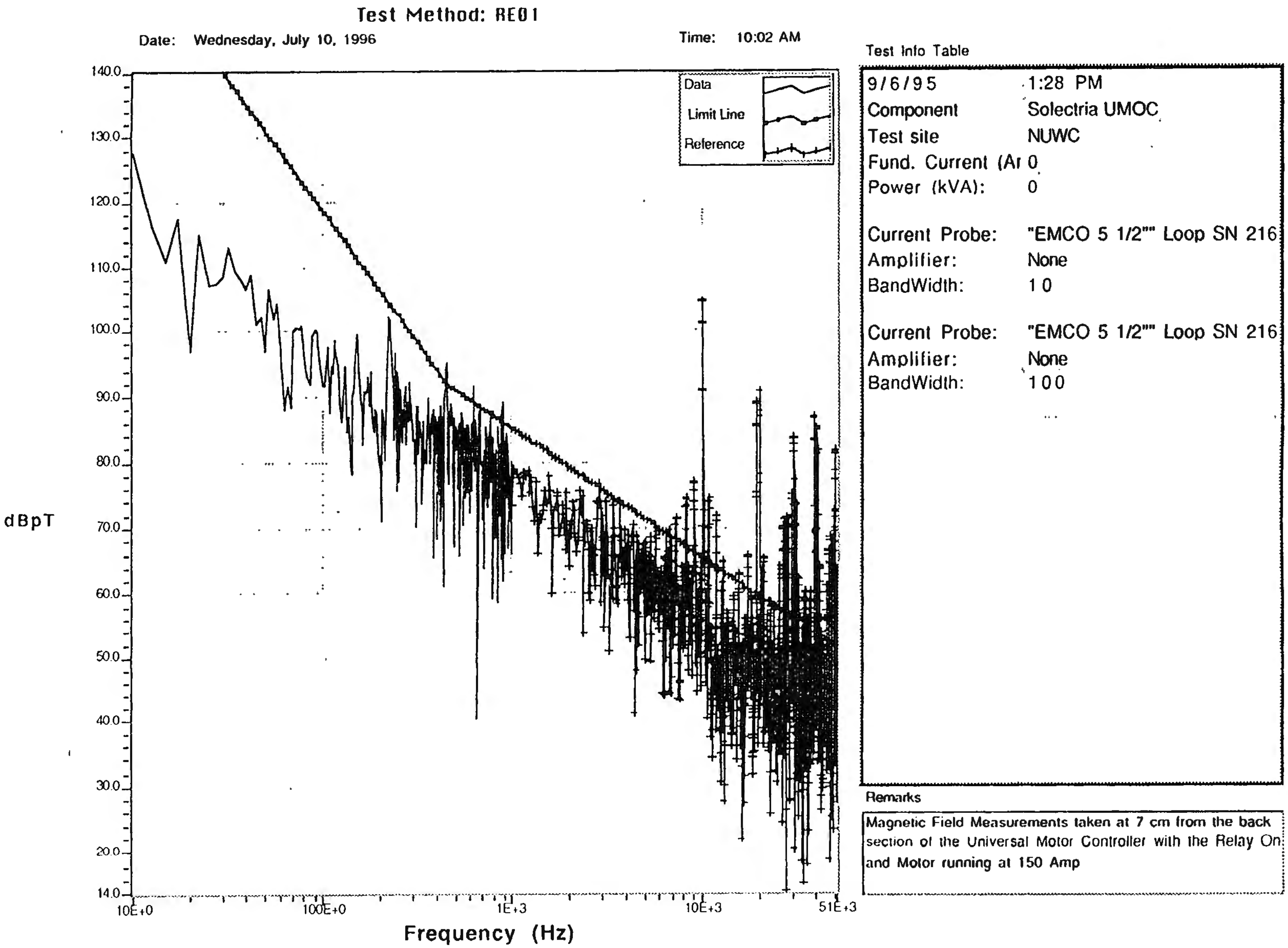


Figure A-44. Solectria Motor Controller in Anechoic Room, B Field Measurements Taken 7cm from the Back Side

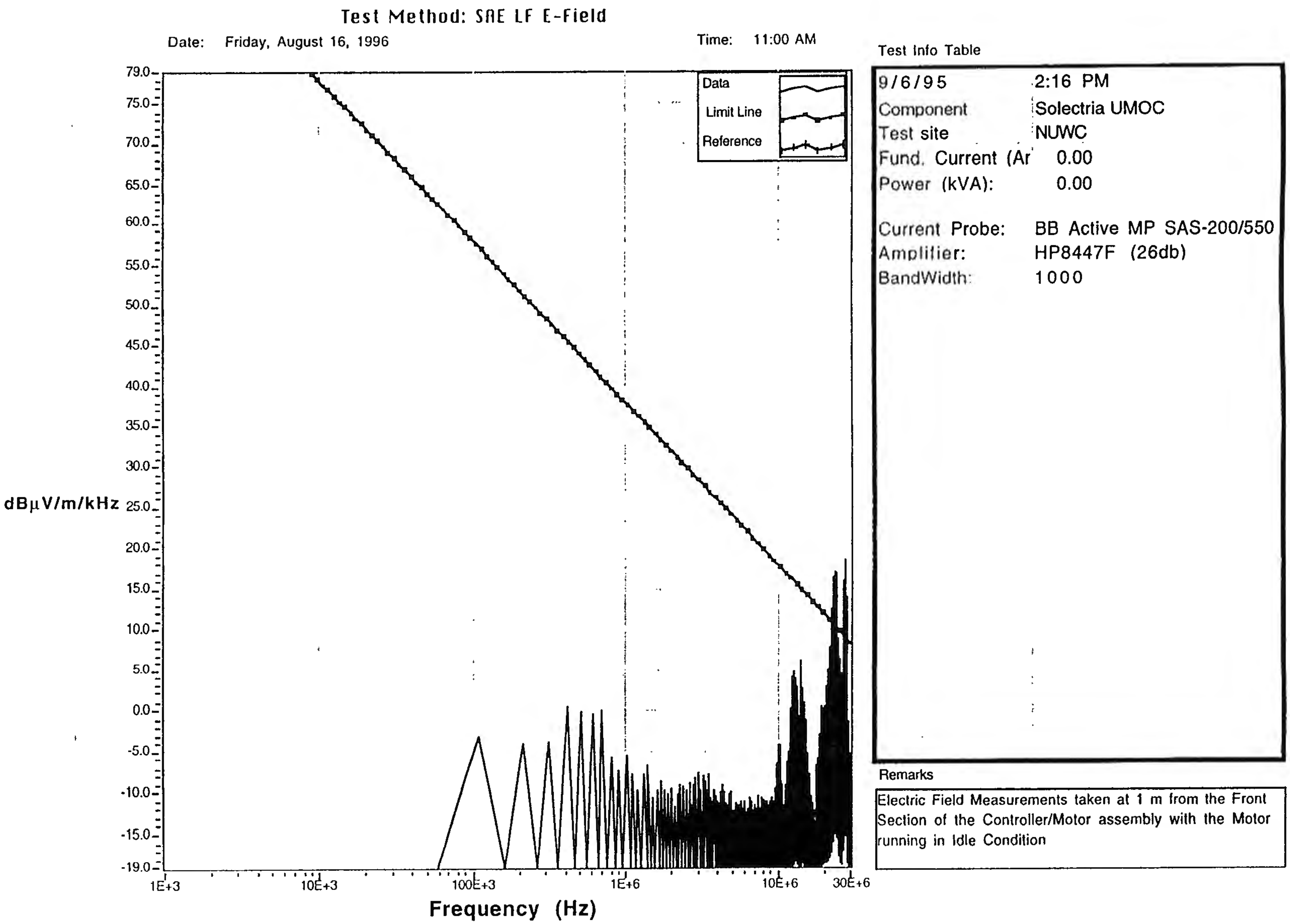
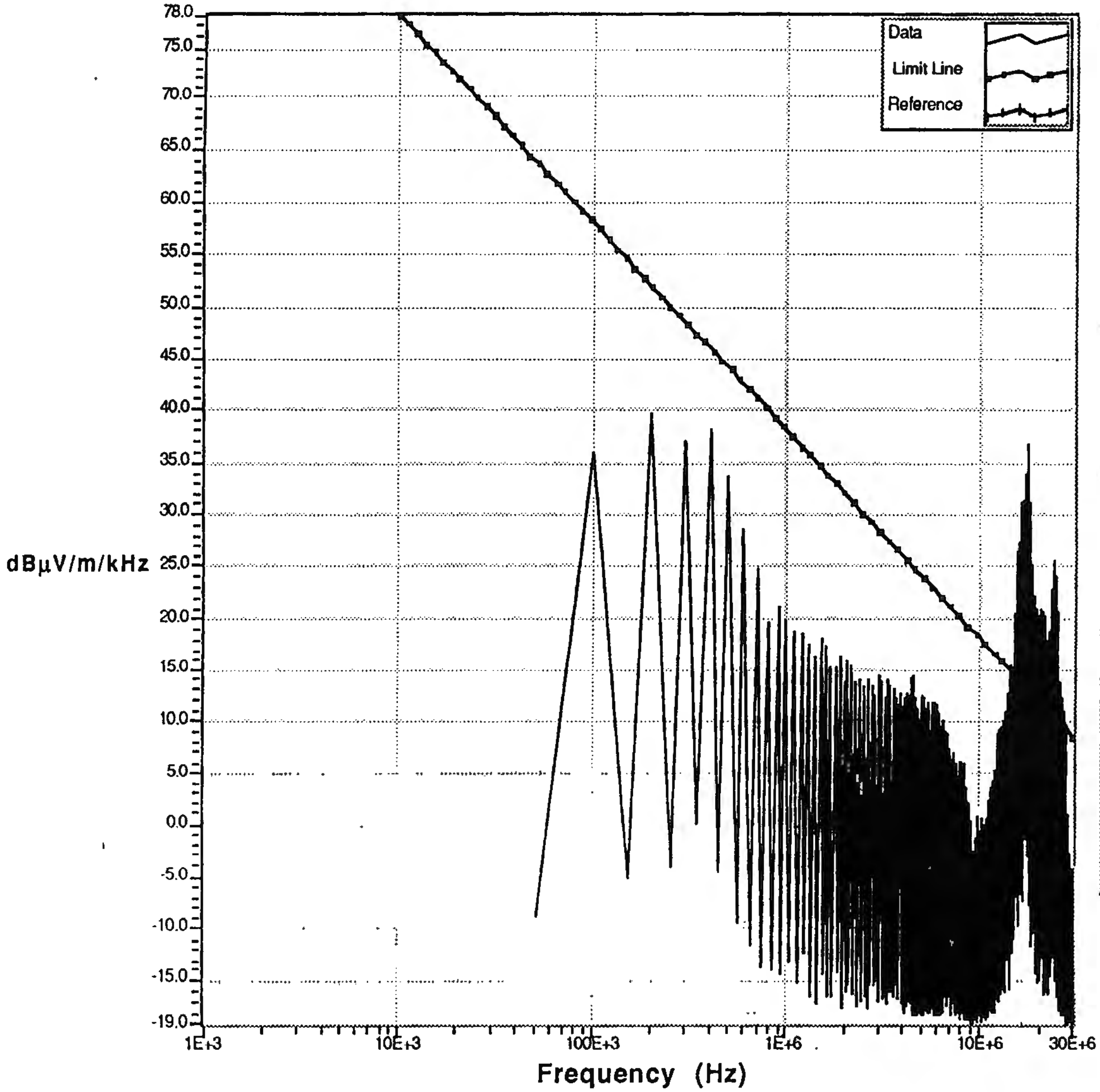


Figure A-45. Solectria Motor Controller in Anechoic Room, E Field (0.009-30 MHz) Taken at Idle Condition

Test Method: SAE LF E-Field

Date: Wednesday, July 10, 1996 Time: 12:11 PM



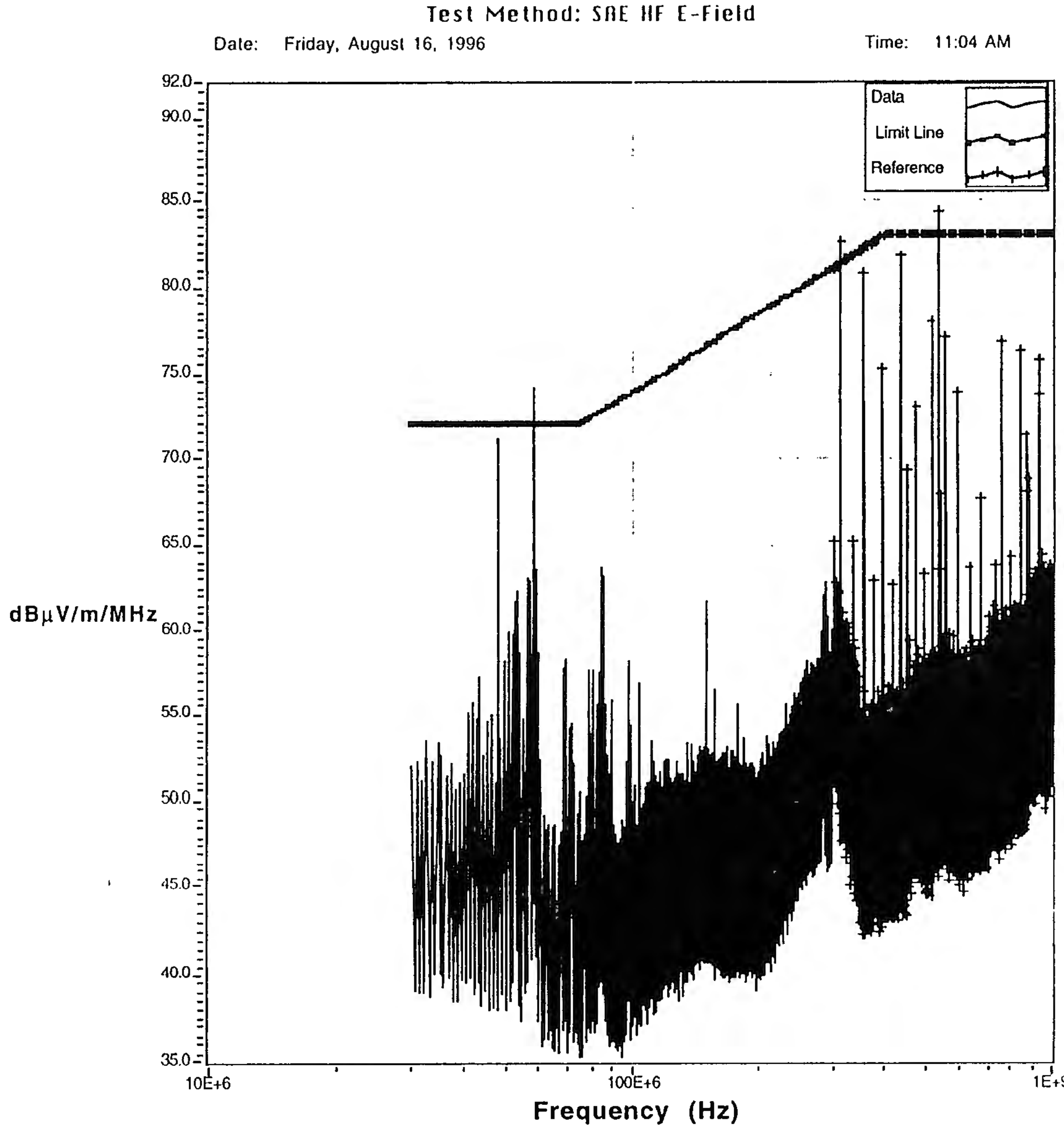
Test Info Table

9/6/95	2:47 PM
Component	Solectria UMOC
Test site	NUWC
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	BB Active MP SAS-200/550
Amplifier:	HP8447F (26db)
BandWidth:	1000

Remarks

Electric Field Measurements taken at 1 m from the front section of the controller/motor assembly with the motor running at 150 Amp on Universal Motor Controller

Figure A-46. Solectria Motor Controller in Anechoic Room, E Field (0.009-30 MHz) Taken 1 m from the Front Side



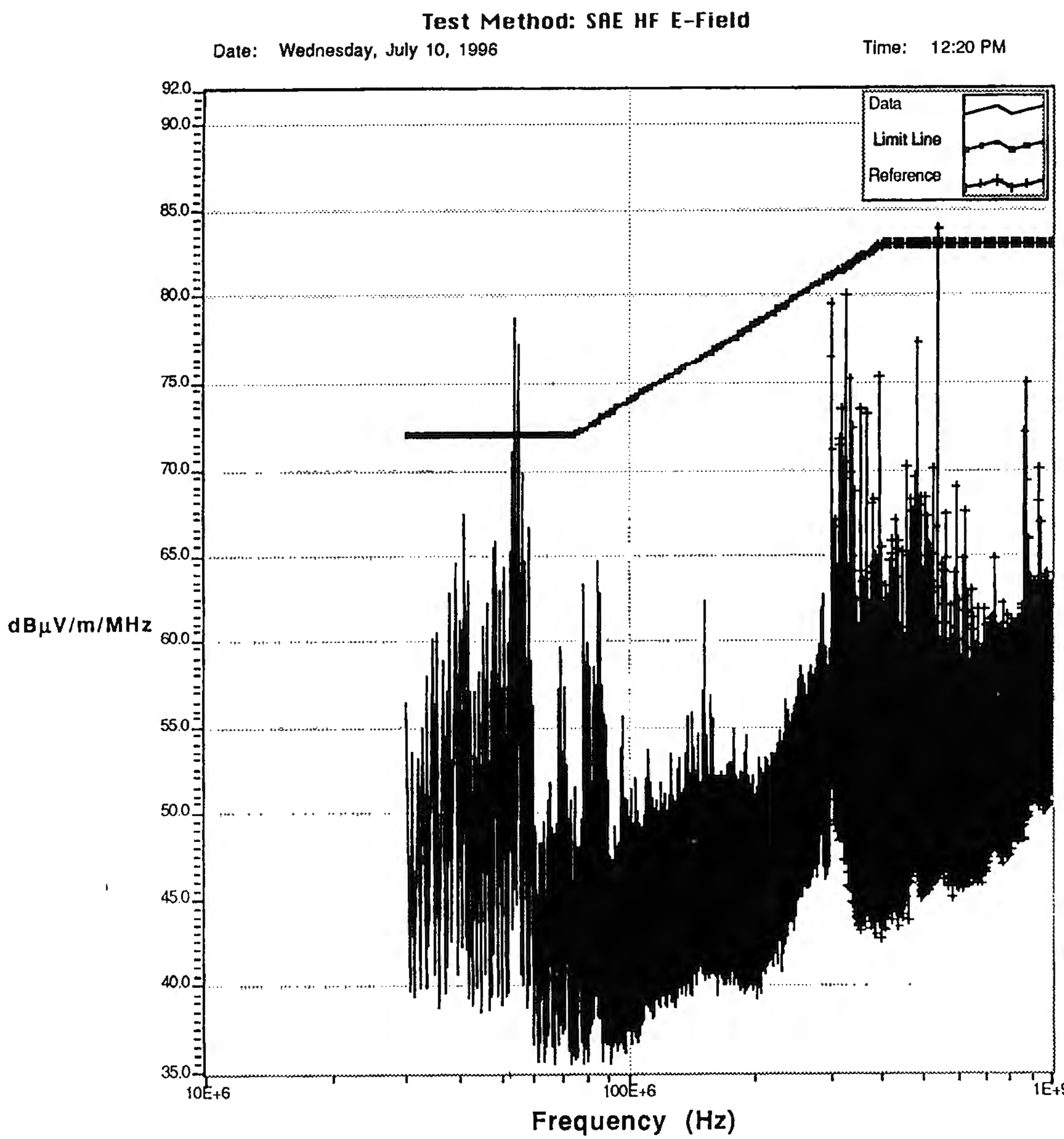
Test Info Table

9/6/95	2:55 PM
Component	Solectria UMOC
Test site	NUWC
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	10000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	10000

Remarks

Electric Field Measurements taken at 1 m from the Front Section of the Controller/Motor assembly with the Motor running in Idle Condition

Figure A-47. Solectria Motor Controller in Anechoic Room, E Field (30-1000 MHz) Taken at Idle Condition



Test Info Table

9/6/95	3:02 PM
Component	Solectria UMOC
Test site	NUWC
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	10000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	10000

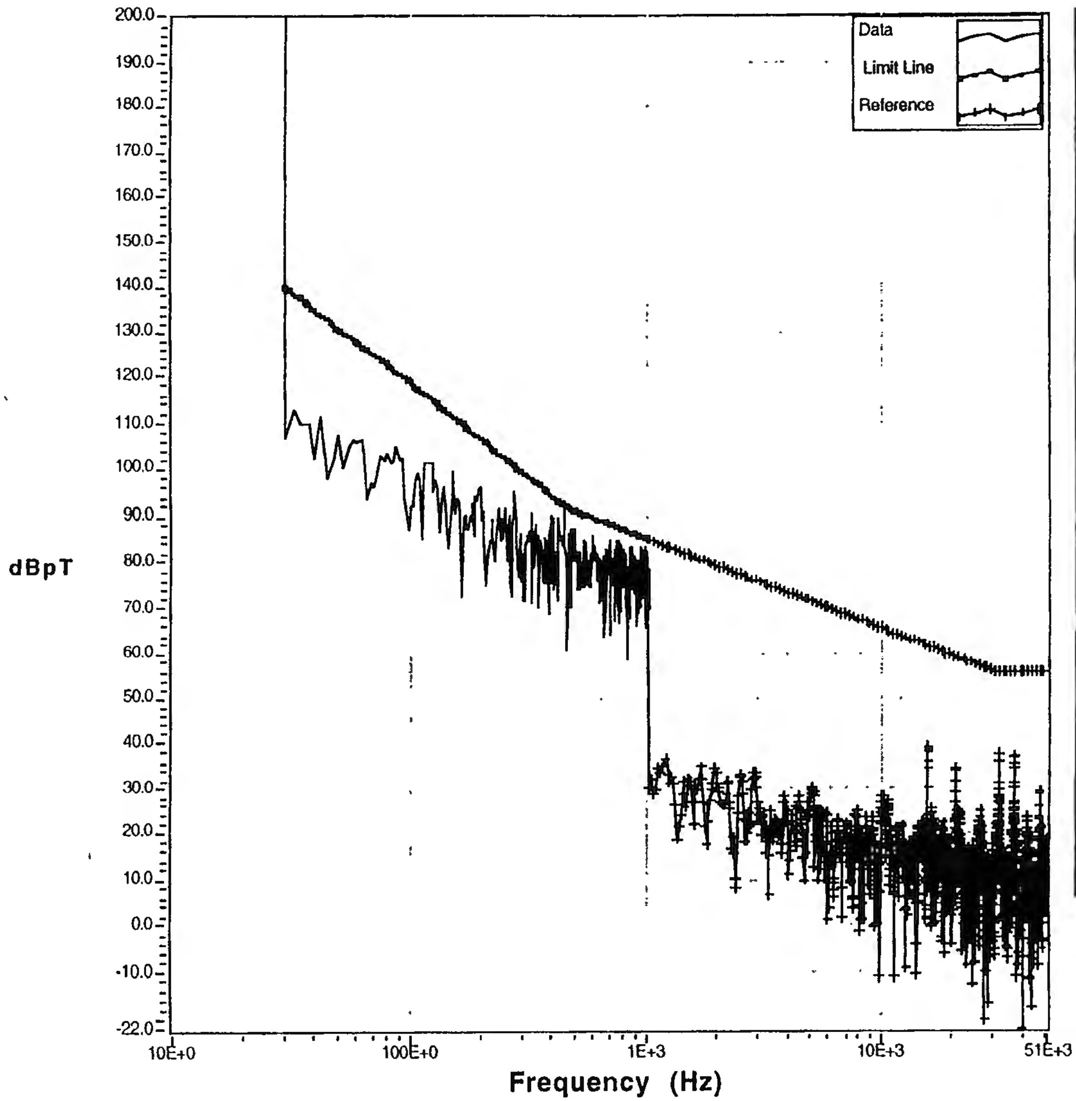
Remarks

Electric Field Measurements taken at 1 m from the front section of Controller/Motor with the motor running at 150 Amp on Universal Motor Controller

Figure A-48. Solectria Motor Controller in Anechoic Room, E Field (30-1000 MHz) Taken 1 m from the Front Side

Test Method: RE01

Date: Friday, August 16, 1996 Time: 11:26 AM



Test Info Table

9/7/95	5:07 PM
Component	Solectria UMOC AC325
Test site	NUWC
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	EMCO 5 1/2" Loop SN 2163
Amplifier:	None
BandWidth:	10
Current Probe:	"EMCO 5 1/2"" Loop SN 216
Amplifier:	None
BandWidth:	100

Remarks

Magnetic Field Measurements taken at 7 cm from the Cables Section of the Controller/Motor type AC325 assembly with the Motor running in Idle Condition

Figure A-49. Solectria Motor Controller AC325 in Anechoic Room, B Field Measurements Taken at Idle Condition

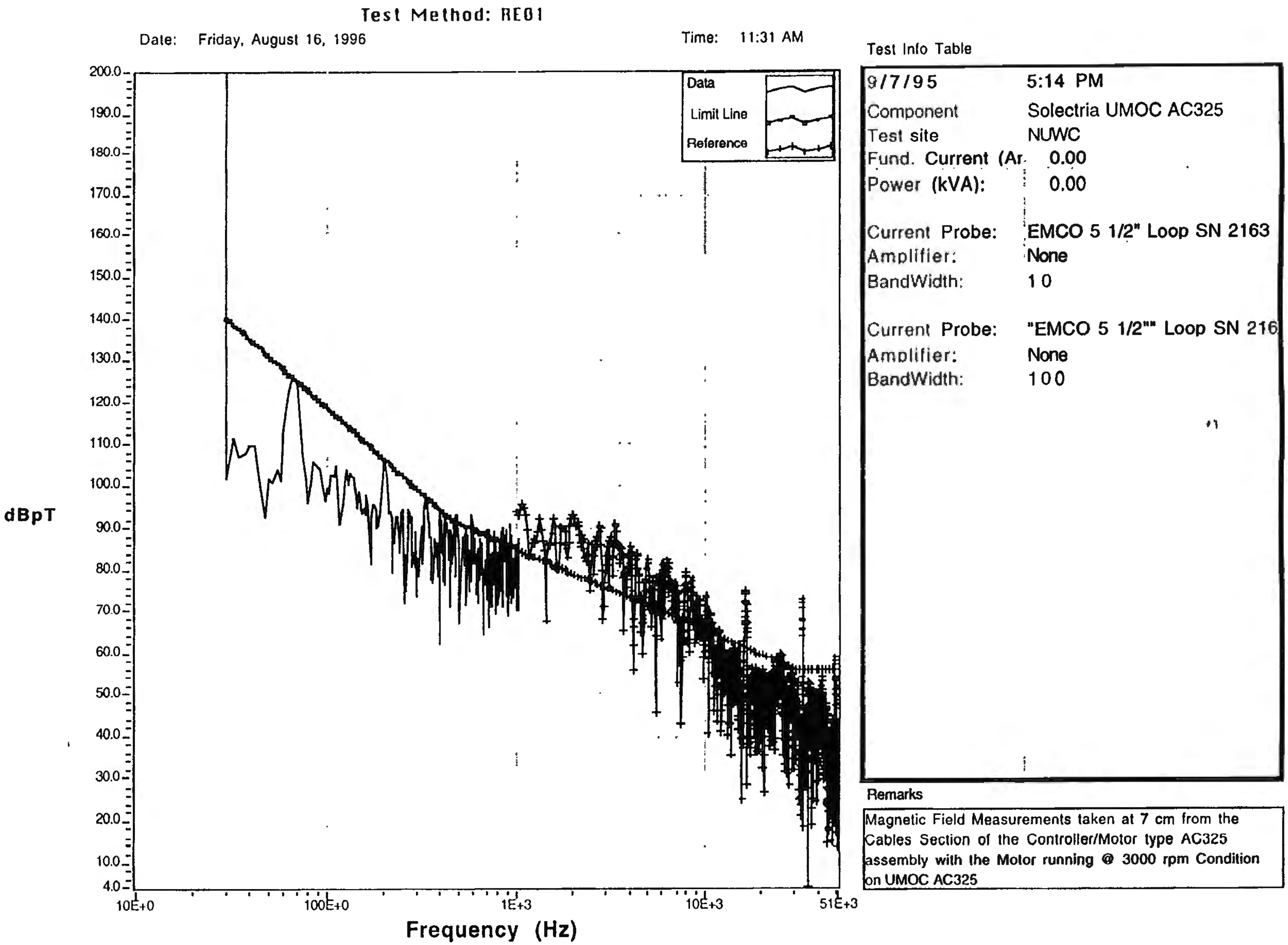
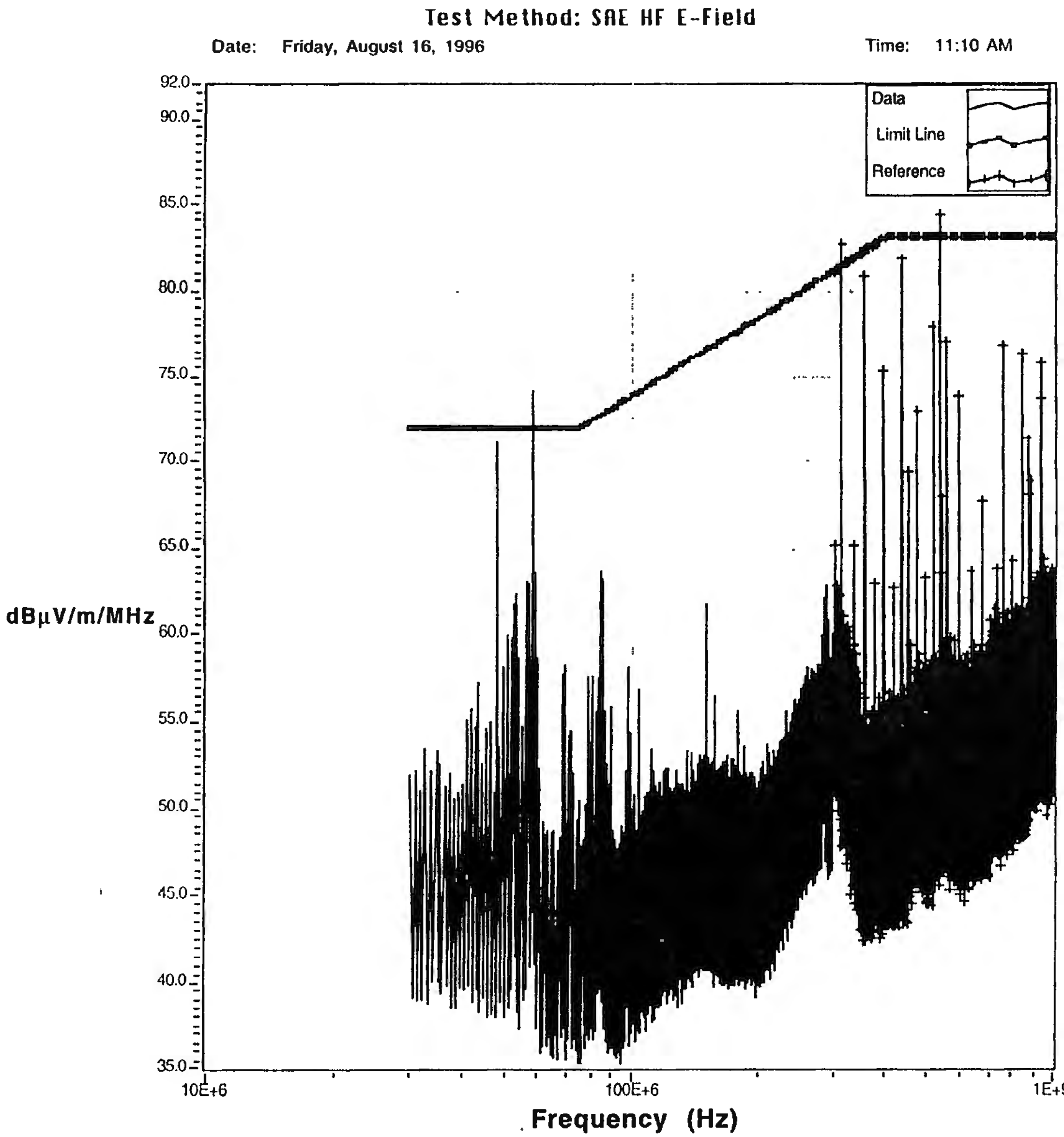


Figure A-50. Solectria Motor Controller AC325 in Anechoic Room, B Field Measurements Taken 7cm from the Cables



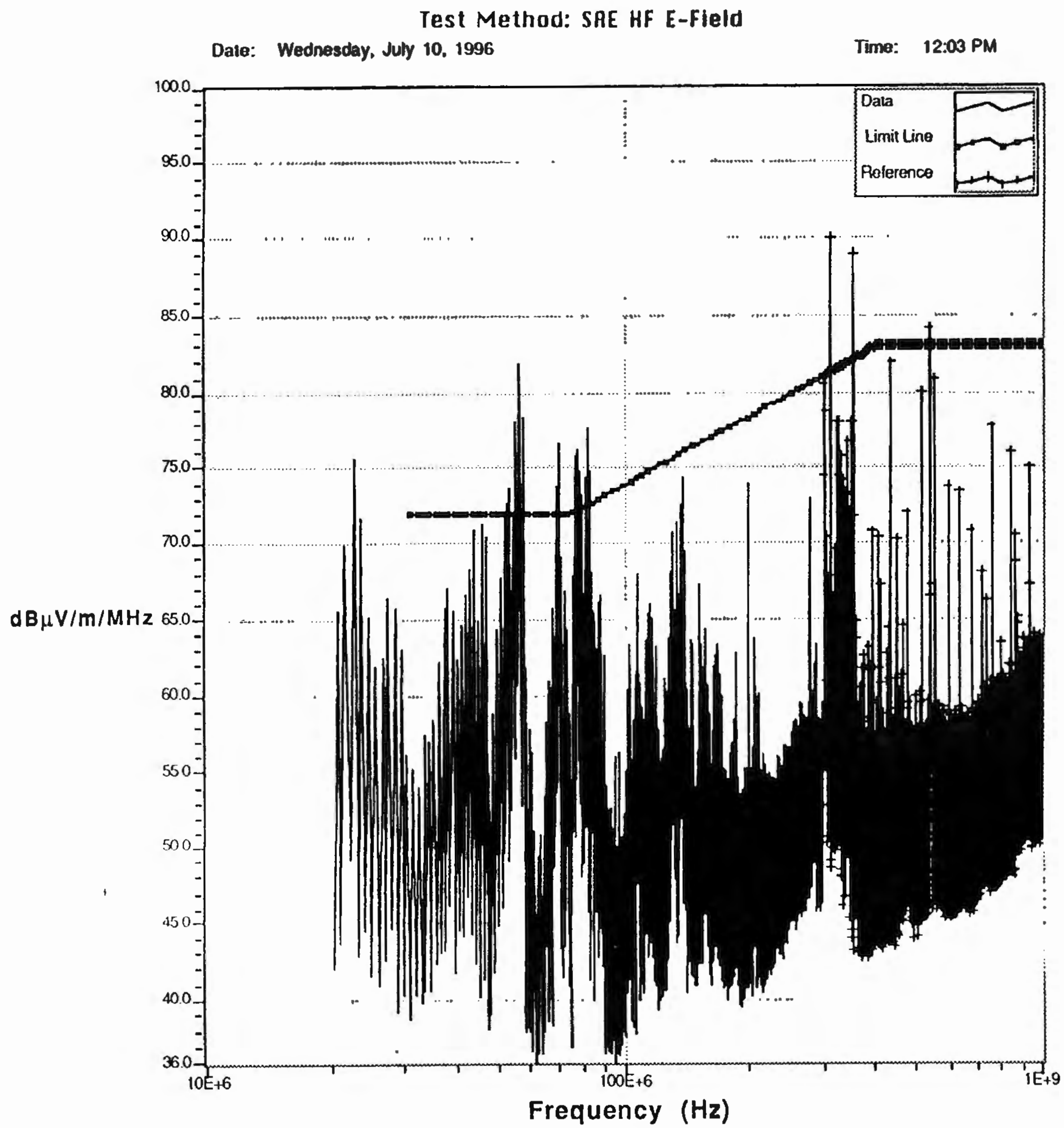
Test Info Table

9/6/95	2:55 PM
Component	Solectria UMOC
Test site	NUWC
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	10000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	10000

Remarks

Electric Field Measurements taken at 1 m from the Front Section of the Controller/Motor type AC325 assembly with the Motor running in Idle Condition

Figure A-51. Solectria Motor Controller AC325 in Anechoic Room, E Field Measurements Taken at Idle Condition



Test Info Table

9/7/95	4:18 PM
Component	Solectria UMOC
Test site	NUWC
Fund. Current (Ar	0.00
Power (kVA):	0.00
Current Probe:	Biconical SAS-200/542 SN
Amplifier:	HP8447F (26db)
BandWidth:	10000
Current Probe:	Log Periodic/SN 426
Amplifier:	HP8447F (26db)
BandWidth:	10000

Remarks

Electric Field Measurements taken at 1 m from the front section of the Controller/Motor of the UMOC type AC325. Motor is running at 60 Amp

Figure A-52. Solectria Motor Controller AC325 in Anechoic Room, E Field Measurements Taken 1 m from the Front

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